HELSINKI UNIVERSITY OF TECHNOLOGY

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Solution Strategies of Service Fulfilment Operation Support Systems for Next Generation Networks

Master's thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Engineering

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TEKNILLINEN KORKEAKOULU Diplomityön tiivistelmä

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Suomalainen operatiivisten tukijärjestelmien toimittaja tarjoaa ratkaisuja palvelujen aktivointiin, verkkoresurssien hallintaan ja laskutustietojen keruuseen. Nämä ratkaisut ovat pääosin käytössä langattomissa verkoissa. Tässä tutkimuksessa arvioidaan kyseisten ratkaisujen soveltuvuutta palvelutoimitusprosessien automatisointiin tulevaisuuden verkkoympäristöissä. Tarkastelun kohteena ovat runko- ja pääsyverkkojen kiinteät teknologiat, joiden suosio saavuttaa huippunsa seuraavan 5-10 vuoden aikana. Näissä verkoissa palvelujen, kuten yritys-VPN:n tai kuluttajan laajakaistan, aktivointi vaatii monimutkaisen toimitusprosessin, jonka tueksi tarvitaan ensiluokkaista tukijärjestelmää.

Teknologiakatsauksen jälkeen tutkimuksessa verrataan viitteellistä tuoteportfoliota saatavilla oleviin operatiivisten tukijärjestelmien arkkitehtuurisiin viitekehyksiin, ja analysoidaan sen soveltuvuus tulevaisuuden verkkoympäristöjen palvelutoimitusprosessin automatisointiin. Myös palvelutoimitusprosessien automatisointiin soveltuvien tukijärjestelmien markkinatilanne arvioidaan, ja tämän perusteella tutkitaan optimaalisinta sovellusstrategiaa. Lopulta voidaan päätellä, että tuoteportfoliolle parhaiten soveltuvin sovellusalue on kuluttajan laajakaistan, ja siihen liittyvien kehittyneempien IP-palveluiden palvelutoimitusprosessien automatisointi.

Avainsanat:

Palvelutoimitusprosessi, operatiivinen tukijärjestelmä, runkoverkko, pääsyverkko, IP-palvelut, laajakaista

HELSINKI UNIVERSITY OF TECHNOLOGY Abstract of Master's Thesis

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A Finnish Operation Support Systems (OSS) vendor provides solutions for service activation, network inventory and event mediation. These solutions have mostly been deployed in mobile environments. In this thesis it will be studied how feasible it is to use similar solutions for service fulfilment in Next Generation Networks (NGN). NGN is a broad term that describes some key architectural evolutions in telecommunication core and access networks that will be deployed over the next 5 to 10 years. In these networks service, e.g. Triple Play or Virtual Private Network (VPN), activations require an extensive service fulfilment process that must be supported by first-class OSS.

After introducing the NGN technologies, the research compares a reference product portfolio to available service fulfilment frameworks and evaluates the applicability. The study analyses the current state of service fulfilment OSS markets and evaluates various solution strategies. Eventually it will be concluded that the most interesting and adequate solution scenario is residential broadband, including value-added IP services.

Keywords:

Service fulfilment, Operations Support System (OSS), NGN, IP services, broadband

Foreword

This thesis evaluates the different strategic choices that any service activation OSS vendor is facing while considering strengthening its presence in the Next Generation Network (NGN) service fulfilment OSS markets. The work has been carried out at Comptel Corp. in 2007.

I want to thank my instructor, Mr. Pekka Partanen from Comptel Corp., and supervisor, Professor Heikki Hämmäinen from the Department of Electrical and Communications Engineering in Helsinki University of Technology. Your feedback and comments helped me to finish the thesis.

I want to also give my appreciation to all my friends, whose encouragement and good example made me work harder. Also, without you I would have missed all the fun.

And towards my parents, I naturally feel a great gratitude for encouraging my studies and providing the opportunity.

Finally, I would like to thank my beloved Sanna. You are amazing.

Joonas Ojala

Espoo, December 2007

Abbreviations

ARPU	Average Revenue Per User
AToM	Any Transport over MPLS
ATM	Asynchronous Transfer Mode
BGP	Border Gateway Protocol
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CE	Customer Edge (router)
CIM	Common Information Model
CLI	Command Line Interface
COTS	Commercial Off-The-Shelf
CRM	Customer Relationship Management
DiffServ	Differentiated Services
DMTF	Distributed Management Task Force
eTOM	Enhanced Telecom Operations Map
ETSI	European Telecommunications Standards Institute
GIS	Geographic Information System
GUI	Graphical User Interface
HLR	Home Location Register
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISP	Internet Service Provider
IT	Information Technology
ITU-T	ITU Telecommunication Standardization Sector
LAN	Local Area Network
LER	Label Edge Router
LSP	Label Switched Path
LSR	Label Switch Router
MAC	Media Access Control
MAN	Metro Area Network
Mbps	Mega bits per second
MIB	Management Information Base
MPLS	Multiprotocol Label Switching
MSO	Multiple System Operator

MTOSI	Multi-Technology Operations System Interface
NEI	Network Element Interface
NETCONF	Network Configuration
NGN	Next Generation Network
NGOSS	Next Generation Operational Systems and Software
OPEX	Operational Expenditure
OSI	Open Systems Interconnection
OSS	Operation Support System
OSS/J	OSS through Java
P router	Provider router
PE	Provider Edge (router)
PON	Passive Optical Network
QoS	Quality of Service
SAN	Storage Area Network
SID	Shared Information/Data model
SLA	Service Level Agreement
SLS	Service Level Specification
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing
TISPAN	Telecoms & Internet converged Services & Protocols for Advanced Networks
TMF	TeleManagement Forum
UI	User Interface
VC	Virtual Circuit
VLAN	Virtual Local Area Network
VoD	Video on Demand
VoIP	Voice over IP
WAN	Wide Area Network
VLAN	Virtual Local Area Network
VMS	Voice Mail System
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
XML	Extensible Markup Language
3GPP	3rd Generation Partnership Project

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1 Introduction

1.1 Problem definition

Incumbent service providers can no longer rely only on well-established voice and mobile services. New service providers are launching competing broadband service offerings, such as Voice over IP (VoIP) and Video on Demand (VoD), with ever-increasing speed. Consumer market is embracing Triple Play, a combination of high-speed Internet and voice and video streaming, while businesses are offered more and more advanced transparent Local Area Network (LAN) services and other solutions utilising Virtual Private Networks (VPN). Though not all expectations have come true yet, the change that affects the network technologies running the services has started already.

Service providers are eagerly looking for ways to sell more services instead of bandwidth, because their average revenue per user (ARPU) is constantly decreasing. However, designing the services on paper is much simpler that at network level. Modern technologies will not come without a cost: ever-increasing network complexity makes, for example, the service fulfilment process more difficult. If the service fulfilment process is unmanaged and activating e.g. a Triple Play service takes days, the service experience will dramatically decrease. The service fulfilment system must be highly automated and must also let the users self-manage their services: if the customer needs to allocate more bandwidth for VPN or Internet subscription, the system must allow that. The flexibility of the service fulfilment system is also vital, because service providers want to shorten the time-to-market for new services.

For any Operation Support Systems (OSS) vendor that has a strong foothold in Public Switched Telephone Network (PSTN) and mobile network service activation, the shift to data networks is not trivial. While in mobile networks the subscriber information is mostly centralised to “service centres”, such as Home Location Register (HLR) and Voice Mail System (VMS), in data networks the intelligence is in the network. For example the process of activating a new service for a subscriber is different: in a mobile network the service is activated simply to a HLR or VMS, while in an IP network several routers might need to be configured. *Network provisioning* - as contrary to *service activation* - not only requires new kinds of OSS modules, but also expertise and knowledge of network architectures.

This research identifies the technologies and available frameworks for service fulfilment in Next Generation Networks (NGN). It also analyses the current state of service fulfilment OSS markets. Eventually, the study will answer to a question:

- What are the most feasible NGN service fulfilment OSS solution scenarios for a traditional service activation OSS vendor?

1.2 Research Scope

Different types of access networks naturally constitute a significant part of NGN architecture. In this thesis the focus will be on wireline access technologies, because the service fulfilment process of wireless and mobile networks is more straightforward and easier to define, as it will be explained. In metro and core networks, Metro Ethernet and Multiprotocol Label Switching (MPLS) technology are seen as essential parts of Quality of Service (QoS) enabled NGN. However, IP Multimedia Subsystem (IMS), which is most commonly referred to as NGN technology, is discussed only briefly, because there is no similar challenge in service fulfilment.

Architectural and strategic analysis of service fulfilment solutions are based on the available frameworks ([eTOM06]). The reference architecture (Chapter 4) is presented only on a modular level, whereas more thorough design and implementation is left for future research.

1.3 Research Methods

The study is based on literature survey. Next Generation Networks (NGN), including Metro Ethernet, Multiprotocol Label Switching (MPLS) and different access technologies, have been widely discussed in literature during the past five years.

Frameworks for service fulfilment OSS are derived from the work of various standardisation bodies, including TeleManagement Forum (TMF) and Distributed Management Task Force (DMTF).

The reference service fulfilment OSS suite (Chapter 4) is based on industry information. It closely resembles available service fulfilment solutions.

Porter’s Five Competitive Forces framework ([Por79]) is used for analysing the current state of service fulfilment OSS markets and for evaluating how feasible it is for a traditional service activation OSS vendor to strengthen its presence in these markets.

1.4 Structure of Thesis

The following flowchart (Figure 1) introduces the general structure of the thesis.

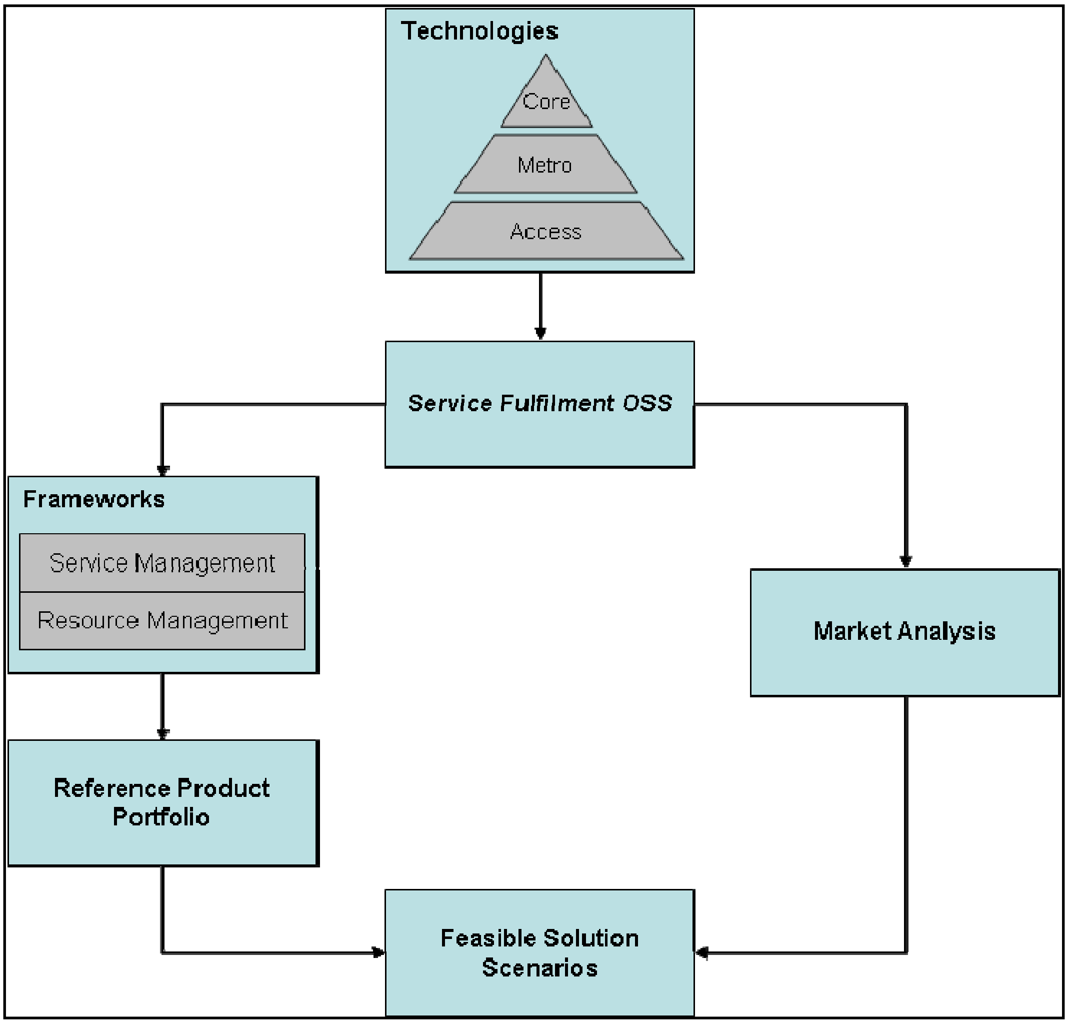

Figure 1 The Structure of the Thesis

Chapter 2 explains Next Generation Network (NGN) technologies and their general architecture. This chapter evaluates the network technologies that network equipment vendors and service providers are currently focusing on.

Chapter 3 introduces the service provider's operational architecture and discusses service fulfilment Operation Support Systems (OSS) in general. The focus will be especially on service and resource management layers, as defined by TeleManagement Forum.

Chapter 4 presents the reference product portfolio, i.e. all software modules that can be used when defining a service fulfilment solution for NGN networks. The general architecture of the service fulfilment solution is also compared to the frameworks discussed in the previous chapter.

Chapter 5 analyses the current service fulfilment OSS markets using Porter's Five Competitive Forces ([Por79]) framework.

Chapter 6 evaluates various strategic approaches for service fulfilment solutions in NGN networks. This chapter introduces different solution scenarios and analyses the most feasible business cases.

Chapter 7 summarises the earlier chapters, condenses the results and gives recommendations for future research.

2 Technology Overview

2.1 Introduction

[ItuY.2001] defines Next Generation Network (NGN) as a packet-based network that is able to provide telecommunication services, make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from the underlying transport-related technologies. NGN networks have several advantages over Public Switched Telephone Network (PSTN) and present-day best effort Internet. [Mod00] lists three main drivers for NGN networks: environmental drivers, service drivers and technology drivers. It is important to notice that it is not only technological advancement that is causing the transition, but the rapidly changing business environment and markets are also playing a vital role.

Environmental drivers reflect the development that has been happening in the telecommunication business environment within the past 15 years. The global telecommunications industry has been moving away from state-owned and regulated monopolies to open-market, competitive industry. Deregulation and privatisation, and the emerging competitive business environment, along with service and technology drivers have caused regrouping and consolidation of not only service providers, but also the system and equipment vendors that serve them.

Service drivers reflect the continuously increasing number of capabilities, and features customers in various markets who demand to meet their constantly evolving set of personal and professional needs. Services are acquired either by end users of services (consumers) or intermediaries (wholesalers) who enhance them and offer to their customers. For example, mobility in general has become an indisputable requirement and service driver. Other market-driven needs include a fluent access to information, ease of use, unified communication capabilities over any medium, greater end-user control over services, and high quality content for entertainment and education purposes. Service and market drivers are unquestionably the ultimate drivers for technological architecture evolution, because services are what customers use and pay for.

Technology drivers include all the technological enablers a service provider, in partnership with its vendors, can benefit from in the process of composing and delivering its set of services. Technology drivers shape customer expectations, thereby modulating service and environmental drivers. Technology drivers were undervalued in the past, while business considerations and short-term customer needs were seen as the only drivers for network evolution. However, the enormous popularity of the Internet along with convergence of distributed computing and communication technologies, have underlined the critical importance of technology drivers in reshaping customer expectations. The Internet, with the technologies it has triggered, is perhaps the single most significant technology driver.

These drivers, along with current day trends - including the growing variety and complexity of new services, the increasing diversity and performance of end-user devices, and the attempt to minimise time-to-market for new services - highlight the importance of fundamental transformation in communication network and service infrastructures. [Mod00]

MPLS is generally accepted to be an essential part of NGN network and service infrastructure, while also being the replacement for ATM technology [Leo03]. Ethernet, on the other hand, has proved to be a very viable LAN technology, and is now seeing even wider adaptation. Ethernet is becoming a popular access and metro network technology, and it is getting more and more carrier-grade transport ([Voo02]) features.

Ethernet enabled access and metro networks, combined with QoS aware IP/MPLS backbone, are also considered new, strong alternatives for carrying traffic in 2G and 3G mobile networks. Today, the mobile core networks are mostly based on TDM or ATM technologies, while PDH, microwave and leased line technologies dominate the access. [Mes07]

However, although MPLS-based services and network products are gaining momentum, as [Mor04] states, neither MPLS nor Metro Ethernet, as a common denominator protocol across multiple services, enable convergence or service interaction. The network equipment and management systems that implement the network must be purpose-built for multiple services and support several service mix scenarios. NGN networks will be a complex mix of different technologies and services, and managing those efficiently will be a challenge. These challenges are discussed more thoroughly for example in [Li05].

In the following chapters we study NGN access, metro and core network technologies. The focus will be on general architectures and concepts, while the later chapters will analyse the service fulfilment issues more thoroughly.

2.2 Metro Ethernet

2.2.1 Overview

Metropolitan Area Network (MAN) is a part of the network that connects subscribers or businesses to Wide Area Network (WAN), such as Internet. In the past metro was implemented primarily using time-division technology (TDM), which was a very suitable technology for delivering voice services. TDM-based technologies, like SDH and SONET, have their restrictions, however: operation and installation of such networks is very troublesome and expensive, because the technologies are very rigid and do not have flexibility or the economics to scale to different customer needs. For example the bandwidth cannot be allocated according to linearly growing user demand, instead it grows in step functions (from T1's 1.5 Mbps to DS3's 45 Mbps, and from this to OC3's 155 Mbps).

Ethernet technology has been widely accepted as Local Area Network (LAN) technology, and Ethernet interface has become very popular. It is estimated that 90% of data traffic is Ethernet encapsulated [Tan05]. When Ethernet technology is applied, high bandwidth requirements can be fulfilled cost-effectively, and the technology also scales much better on linearly increasing user demand than TDM-based technologies. Service provisioning is faster as well, because only software parameters must be modified – not network equipment or interfaces. Therefore, extending the scope of Ethernet technology, and replacing legacy technologies with Ethernet in Metropolitan Area Network (MAN) introduces many advantages to both the service provider and the subscriber (both business and residential). [Hal03]

2.2.2 Architecture

Ethernet is a Layer 2 service that uses Media Access Control (MAC) addresses for switching. By contrast to Layer 3 IP addresses, MAC addresses identify the hardware itself, are unique in most cases, and thus cannot be defined by network administrators. When an Ethernet packet arrives at the switch, the switch validates the packet's destination MAC address and, if known, sends the packet to the port from which it learned the destination MAC address. MAC learning enables the Ethernet switch to know MAC addresses of the stations in the network, and therefore identify to which port to forward the traffic. Ethernet switches typically contain one MAC learning table which maps the MACs and virtual

LANs (VLAN) with a given port, and another VLAN table that associates the port with a VLAN.

VLAN is another fundamental element in Ethernet switching. Using VLANs, LAN (or MAN in larger scale) can be divided into logical entities. For example broadcast messages are typically forwarded to all physical segments of the LAN, but when VLANs are applied, broadcast traffic is isolated according to the VLAN the sending station belongs. Flooding is a concept that allows packets to be forwarded to correct destinations, even though the Ethernet switch would not know the exact location of the destination MAC address. If the MAC learning table does not contain the destination MAC address, the packet is sent to all interfaces that belong to same VLAN as the sender. The disadvantages of flooding are the extra resources it consumes from the switch and network, but with proper usage of VLANs the effect can be reduced.

VLAN tagging means the procedure where an Ethernet packet (frame) gets tagged with VLAN ID. VLAN tagging is defined in IEEE 802.1Q ([Ieee802.1q]). The Ethernet switch assigns a VLAN number to a port, and once this port receives a packet, the packet will be tagged with that VLAN ID. The VLAN ID field in an Ethernet frame is 12 bits long, and therefore only 4096 (2^{12}) different VLANs are supported – which is insufficient in a MAN environment. For this reason different companies have introduced their own versions of *VLAN stacking*, which basically means doing multiple VLAN taggings to the same Ethernet frame (creating a pile of VLAN IDs) - e.g. inner VLAN ID applies in customer network and outer one in provider network. VLAN stacking is often referred to as Q-in-Q, in accordance to Cisco Systems' implementation.

Another scalability problem is the increased size of MAC address tables of core switches. These switches have to carry traffic coming in from many VLANs in the network. Figure 2 illustrates how switches are connected to each other in the core. As shown in Figure 2, trunk ports (ports of switch S2 and ports of switches S1 and S3 interfacing S2) are carrying the traffic of several VLANs, whereas access ports are assigned only with one VLAN. [Hal03] Eventually, this means that core switches need to learn all customer MAC addresses, and therefore the size of MAC address tables will explode. This problem can be alleviated with MAC-in-MAC (also referred to as Provider Backbone Bridging) encapsulation, where the ingress node inserts the source (ingress node) and destination (egress node) MAC address to the Ethernet frame. These addresses have local significance within the metro domain, and this way core switches have to learn only the edge switch MAC addresses. [Ali05]

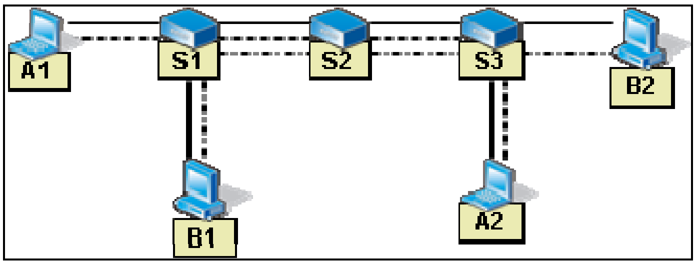

Figure 2 Virtual Local Area Network

IEEE standard, IEEE 802.1ad ([Ieee802.1ad]), defines two different VLAN entities: Customer VLANs (C-VLANs) that are controlled by a single customer of a service provider and Service VLANs (S-VLANs) that are used by a service provider to support different customers. Along with new IEEE standard that is in the draft stage ([Ieee802.1ah]) in autumn 2007, the standards will allow service providers to scale the number of VLANs in a provider network, and also enhance the interoperability and consistent standards based management.

Although new standards improve the interoperability between network equipments from different vendors, some problems still exist. When core network size increases, the switched Ethernet loses its simplicity because managing VLAN assignments becomes a very complex task. If VLAN assignments are incorrect, traffic will not be switched to correct ports. Ethernet also has no signalling mechanisms, and thus the only way to make VLAN allocations more manageable is to use some third-party applications. But these mechanisms are also mostly limited to small enterprise environments, and they will become a showstopper in larger enterprise deployments or carrier networks. So eventually Ethernet will need support from some signalling mechanism, and currently the most feasible and popular solution is to run Metro Ethernet on top of MPLS and this way gain the benefits of LDP signalling. This will be discussed more in Chapter 2.3.3. [Hal03]

2.2.3 Services

Metro networks typically offer several different services, such as Internet connectivity, transparent LAN service (point-to-point LAN to LAN), L2VPN (point-to-point or multipoint-to-multipoint LAN to LAN), LAN to network resources (remote data centre), extranet, LAN to Frame Relay/ATM VPN, storage area networks (SANs), metro transport (backhaul) and VoIP. Services like Internet connectivity and transparent LAN service have been available for several years, but the difference is that with Ethernet, all additional services can be provided over the same infrastructure. Also, some of the services, like SANs and remote data centres, could not have even existed in past, because TDM based technologies were unable to provide enough bandwidth. [Hal03]

Metro Ethernet Forum (MEF) is an industry consortium focusing on development of carrier grade Ethernet ([Voo02]) and services. Figure 3 ([San06]) presents the basic model of Metro Ethernet Network (MEN). Customer Equipment (CE) is attached to MEN through UNI (User-Network Interface) using a standard 10Mbps, 100Mbps, 1Gbps or 10Gbps Ethernet interface.

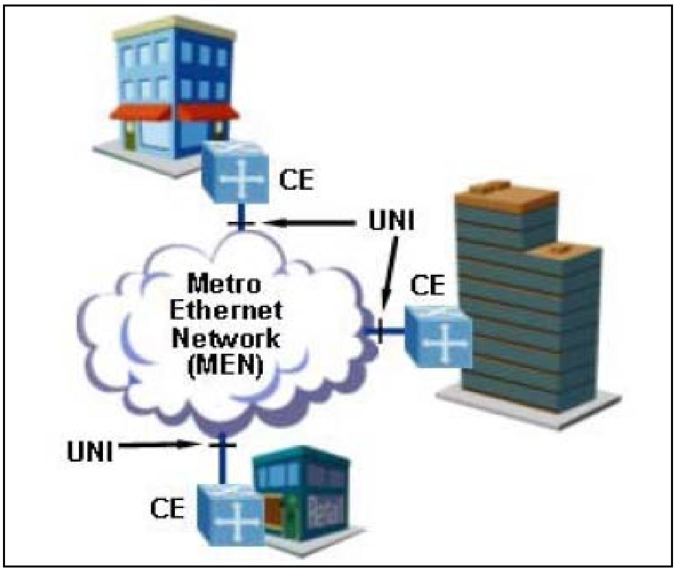

Figure 3 Metro Ethernet Basic Consepts [San06]

Two or more sites can be connected together using Ethernet Virtual Connections (EVC), which also ensure that no data is delivered to sites that do not belong to the same EVC. EVCs can be either Point-to-Point or Multipoint-to-Multipoint and they enable construction of Layer 2 Private Line (E-Line Service) or Virtual Private Network (E-LAN Service). Naturally, EVCs are closely related to VLANs – one or more VLANs build up an EVC. E-Line and E-LAN Services are used as building blocks in defining Metro Ethernet services. Other basic concepts when defining the Metro Ethernet services are Ethernet Service Attributes: Ethernet Physical Interface, Bandwidth Profile, Performance Parameters, Class of Service Identifiers, Service Frame Delivery, VLAN Tag Support, Service Multiplexing, Bundling and Security Filters. From the service activation point of view, especially Bandwidth Profile (defines the bandwidth for UNI), Class of Service (whether QoS is applied according to physical port, VLAN ID or DiffServ / IP Type of Service values), Service Multiplexing (to which VLANs a subscriber should be added and how to use VLAN tagging) and Security Filter (e.g. grant access to UNI only from certain Ethernet MACs) attributes are interesting, because they must be defined before the customer can access the service and therefore there is a need for a larger scale provisioning. Metro Ethernet services and service attributes are covered thoroughly in [San06].

2.3 Multiprotocol Label Switching

2.3.1 Overview

Multiprotocol Label Switching (MPLS) has become a popular networking technology in the past few years. MPLS uses labels attached to IP packets (other protocols are also supported) to forward them through the network. In relation to OSI reference model ([Iso7498]), MPLS is neither Layer 2 nor Layer 3 technology, which sometimes causes confusion.

The MPLS labels are advertised between routers, and thus routers are able to create label-to-label mapping. Labels are then attached to IP packets and forwarded according the labels instead of destination IP address. The forwarding scheme is called label switching (in contrary to IP switching), which is quite similar to the forwarding method used by Frame Relay and ATM. [Ghe06]

2.3.2 Architecture

MPLS label is 32 bits long, consisting of the 20 bits long label value, 3 experimental bits that are used for QoS, Bottom of Stack (BoS) bit which identifies the bottom label in the stack and 8 Time To Live (TTL) bits ensuring that packet will not be stuck in a routing loop. Labels can be stacked, which means that more than one label on top of the packet is used to route the packet through MPLS enabled network. Label stacking is required by some MPLS applications, such as MPLS VPN and AToM (Any Transport over MPLS). MPLS label or label stack resides between the Layer 2 header (e.g. Ethernet) and transported packet (e.g. Layer 3 IP packet), and is often referred to as *shim header* because of its placement. Being located between two layers, MPLS does not precisely fit to OSI layering.

A router that supports MPLS is called a Label Switch Router (LSR). LSR understands MPLS labels and is capable to receive and transmit a labelled packet in a data link. LSR routers can be divided into three categories: ingress, egress and intermediate LSRs (Figure

3). An ingress LSR inserts label(s) to packets that have not been labelled yet and forwards the packets on a data link, whereas an egress LSR receives a labelled packet, removes the label(s) and sends it on a data link. Ingress and egress LSRs are sometimes referred to as Label Edge Routers (LER). Intermediate LSRs perform either pop, push or swap operation to label(s) and then send the packet forward. Ingress and egress LSRs are sometimes also called Provider Edge (PE) routers and intermediate LSRs Provider (P) routers. Originally these terms were used only in the case of MPLS VPN, but nowadays they are also used even when the MPLS network does not support MPLS VPN.

A Label Switched Path (LSP) is a sequence of LSRs that switch a labelled packet through an MPLS network. In other words, it is the path that a packet travels in an MPLS network. LSPs are unidirectional, which means that two LSPs must be established for bidirectional connection. Packets that use the same LSP and are treated the same in regard to the forwarding treatment belong to same Forwarding Equivalence Class (FEC). Ingress LSR classifies and labels the packets and therefore decides which FEC the packet belongs to. FECs can be divided for example according to Layer 3 destination IP addresses, precedence of IP DiffServ Code Point (DSCP) field or Layer 2 virtual circuit (VC).

Label distribution protocol is needed, because the routers need to know which labels to use when forwarding a packet. The LSR must be able to figure out which outgoing label the incoming label should be swapped with. Labels could be distributed either by piggybacking the labels on an existing IP routing protocol or by having a separate protocol for distributing the labels. Although the first method would not require a new protocol to be run on the LSRs, every existing IP routing protocol should be extended to carry the labels. As result, none of the Interior Gateway Protocols (IGP) have been changed to support it. However, Border Gateway Protocol (BGP), that is able to carry prefixes and labels at the same time, is used for label distribution in MPLS VPN networks.

Separate protocol has been the primary solution for distributing labels. Label Distribution Protocol (LDP) is the most common alternative for distributing labels, but others also exist: Tag Distribution Protocol (TDP, proprietary Cisco protocol that preceded LDP) and Resource Reservation Protocol (RSVP, used for MPLS Traffic Engineering). Label distribution with LDP operates so that the LSR creates a local binding for every IGP IP prefix, i.e. binds a label to the IP prefix, in its IP routing table. The LSR then distributes this binding to all its LDP neighbours, which then stores it to Label Information Base (LIB) as remote binding. Figure 4 highlights how the packet travels through the MPLS enabled network, once the labels are correctly exchanged between LSRs.

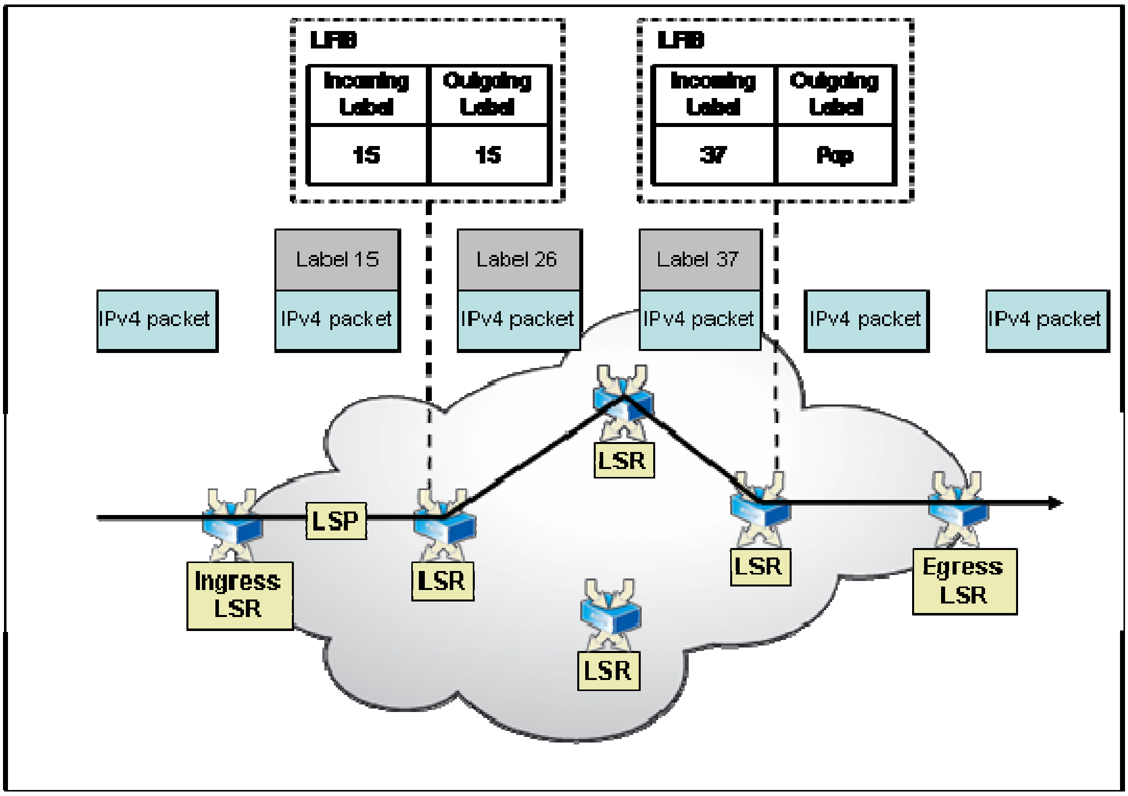

Figure 4 Packet Forwarding in MPLS

In Figure 4 the LFIB stands for Label Forwarding Information Base that is derived from LIB and Forwarding Information Base (FIB, derived from IP routing table) entries.

2.3.3 Services

MPLS enables use of one unified network infrastructure, making it possible to also carry other protocols besides IP over MPLS enabled Layer 3 IP backbone. MPLS also offers better IP over ATM integration than previous technologies. This is important, because ATM became a relatively popular WAN protocol in the core of the service provider network, and when these service providers also eventually deployed IP backbone, the integration of IP over ATM was not trivial.

In addition to being a unifying technology, MPLS applications enable several QoS sensitive services. MPLS Virtual Private Network (VPN) is the most popular MPLS application, allowing service providers to emulate a private network over common infrastructure in a scalable manner. Another MPLS application, Virtual Private LAN Service (VPLS), can be also used for constructing VPN functionality, but the difference is that it operates on layer

2. MPLS also offers efficient tools for traffic engineering, allowing service providers to optimize the usage of their network infrastructure.

MPLS VPN

MPLS Virtual Private Network (VPN) [Rfc4364] is the most widespread implementation of MPLS technology. MPLS VPN is also sometimes referred to as BGP/MPLS VPN, where BGP implies to protocol that is used for distributing routing information. Many service providers have deployed it as a replacement for Frame Relay and ATM services, and large enterprises are also showing growing interest in it. With MPLS VPN, the common IT infrastructure of large enterprise networks can be divided into smaller and isolated networks in scalable manner. Interconnection of MPLS VPN networks is also a growing trend – service providers are looking for ways to interconnect their MPLS VPN networks with other service providers' MPLS VPN networks to improve the scalability and operability of their network.

Traditionally service providers have deployed their VPNs using overlay VPN model. In overlay model, the service provider supplies a service of point-to-point links or virtual circuits between customer's routers across its network. This can be done either in layer 1 (TDM, E1, E3, SONET/SDH), layer 2 (X.25, ATM, Frame Relay) or layer 3 (IP). MPLS VPN utilises peer-to-peer VPN model, in which service provider routers carry the customer data across the network, and also participate in the customer routing. Prior to MPLS, peer-to-peer VPN model required lots of provisioning, because adding one customer site demanded configuration changes in other sites.

In MPLS VPN, one customer router, called customer edge (CE) router, peers at the IP layer with at least one service provider router, called provider edge (PE) router. The privacy in MPLS VPN networks is achieved by using the concept of virtual routing/forwarding (VRF), which basically means that the PE router keeps the routing information from different customers separately. Each customer can also have their own IP addressing schemes, because MPLS backbone forwards the packets based on label information, not the information in the IP header. Figure 5 represents the basic MPLS VPN deployment scenario.

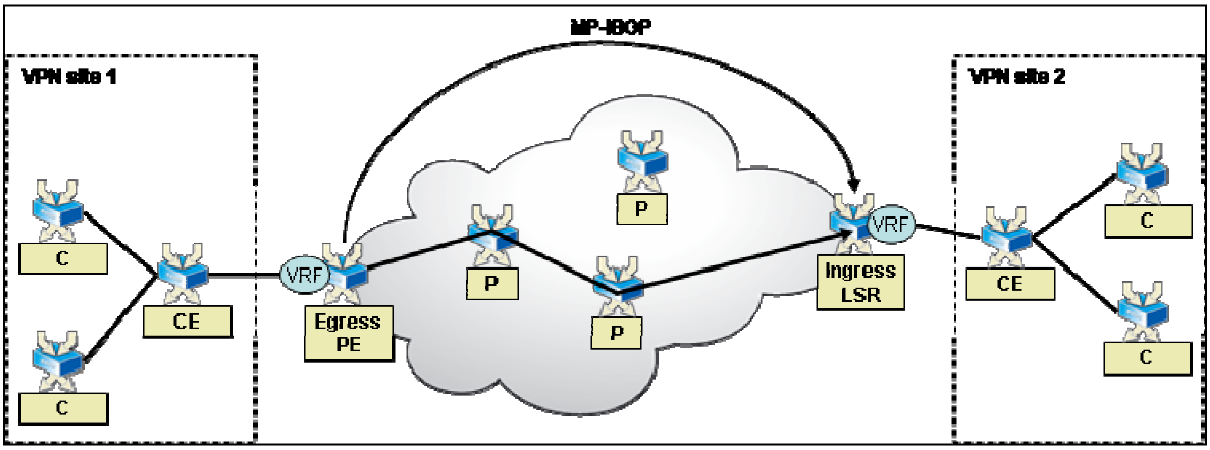

Figure 5 MPLS VPN Basic Consepts

In Figure 5, C routers are customer routers that do not have direct connection with the PE router, and P routers are provider routers that also run MPLS but are completely unaware of the VPNs. Interior Gateway Protocol (IGP), such as OSPF, must be run between CE and PE routers to populate the customer routes into VRF routing table on the PE router. Then, Multiprotocol iBGP (MP-iBGP) [Rfc3107] distributes these customer routes between PEs. P routers do not need to run BGP or know anything about VPNs, because they switch the traffic based on labels that are distributed with LDP. MPLS VPN and its different concepts are explained more thoroughly in [Ghe06].

Virtual Private LAN Service (VPLS)

MPLS VPN service is IP centric, which means that no other layer 3 traffic can be carried across the MPLS backbone with MPLS VPN. Virtual Private LAN Service (VPLS) operates on layer 2 and emulates Ethernet LAN segment across the MPLS backbone through pseudowires or virtual circuits (which are basically LSPs). Ethernet VPLS allows service providers to create one or more completely separate LAN segments for each customer. A customer with several Ethernet sites connecting to VPLS enabled MPLS backbone sees that all the sites are interconnected through virtual Ethernet switch. VPLS is a point-to-multipoint service, whereas Ethernet over MPLS (EoMPLS) and Any Transport over MPLS (AToM) are layer 2 point-to-point services.

Each VPLS instance requires full mesh of pseudowires between participating PE routers, which communicate together using LDP. Figure 6 highlights the main concepts of VPLS.

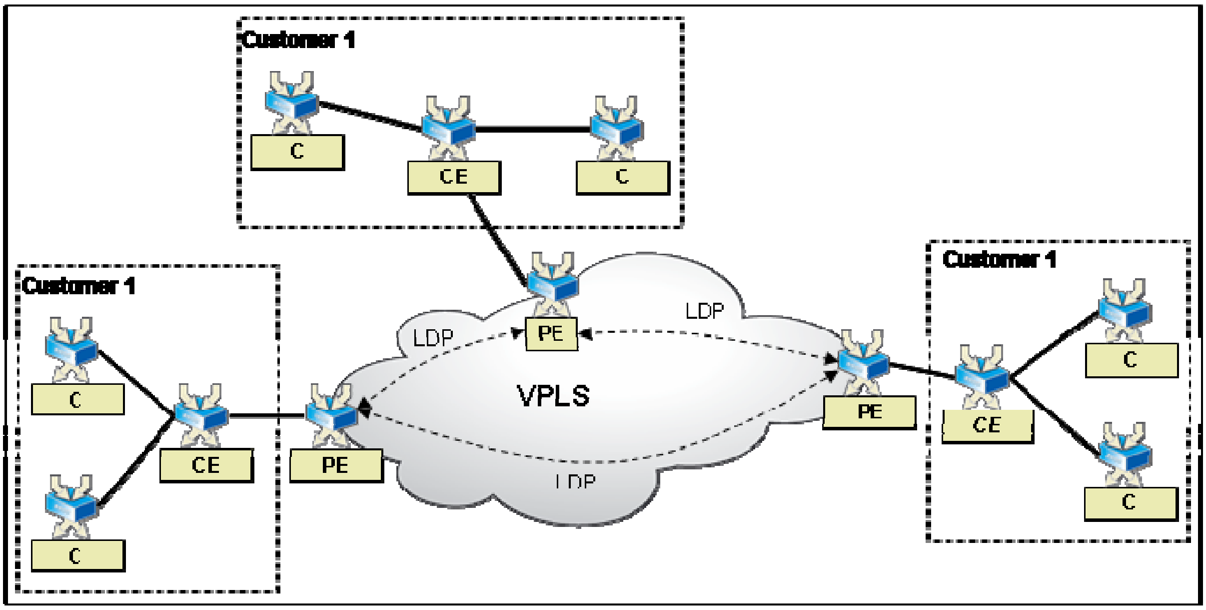

Figure 6 VPLS Basic Consepts

More information about VPLS and its configuration can be found from [Ghe06].

MPLS Traffic Engineering

IP routing is based on the least-cost routing principle, where the cost is a single metric assigned to links in the network. Routers forward packets solely based on the destination IP address, without taking the available bandwidth into account. This can lead into overutilisation of some links and underutilisation of others. With traffic engineering the traffic can be balanced between the links. MPLS supports several traffic engineering features. It takes into account the configured (static) bandwidth of links and dynamic attributes (delay, jitter etc.), and is able to automatically adapt to changing network conditions. In principle, traffic engineering can be implemented by establishing several LSPs between two locations, and letting the MPLS traffic engineering function to balance the traffic between LSPs.

Guaranteed QoS, without losing the efficient usage of network resources, can also be achieved in IP networks by combing MPLS and Differentiated Services (DiffServ, [Rfc2475]) technologies. Network must adaptively adjust to varying network conditions in order to preserve reasonable level of QoS. When DiffServ strategy is applied, different DiffServ classes are mapped to separate LSPs, and this way each service receives the necessary bandwidth. Managing this kind of functionality is not a trivial task, because various issues must be considered: setup of LSPs, capacity allocation of LSPs and LSP routing. Also, network state must be constantly monitored, because only then network configuration can adaptively reflect to changing traffic conditions. MPLS contain several Operation and Maintenance (OAM) features, such as LSP Ping, that can be used in this. Based on measured network state LSPs are added or deleted, dimensioned and routed. Network management tool providing the described functionality is presented in [Sco04] and further analysed in [Anj05]. It involves a measurement and performance evaluation module, simulation module and a tool for automatically configuring the routers and switches.

2.4 Access Networks

Access network, which is sometimes called last mile or local loop, plays an essential role in NGN networks and services. If access networks are lacking of bandwidth, QoS or other necessary attributes, NGN services cannot be provided to customer. So far, according to [Dsl07], DSL has been the most popular broadband access technology with its 65.7% share of all broadband deployments. Two other access technologies with significant market share are cable (22.3%) and fibre to home or other close location (FTTx) (10.5%). The share of satellite technology is only 0.3%, and other access technologies, such as E3/T3 “leased lines” allocated to business subscribers, 1.1%. The dominant access network technologies are described in the following sub-chapters.

2.4.1 DSL

As the statistics ([Dsl07]) show, local loops still primarily consist of copper telephone wires (twisted pair). DSL technology utilises copper wires and can provide downstream data speeds starting from 8 Mbit/s of Asynchronous DSL (ADSL) to 24 Mbit/s of ADSL2+, and ultimately to 250 Mbit/s of Very High Speed DSL 2 (VDSL2). However, bandwidth is severely limited by distance and quality of copper wires. For example the downstream speed of VDSL2 decreases to 100 Mbit/s if the local loop is longer than 0.5 kilometres and decreases even more dramatically when distance grows. In order to make DSL a more viable solution, operators would have to add active DSL components deeper in the network, but this would make the already difficult provisioning process even more time-consuming and increase the cost of operations and maintenance [Bal05]. One solution for alleviating the issues with copper based local loop is to implement an advanced DSL management system that contains information about the quality of copper wires and other relevant attributes. Though building up such a system can be complex and expensive, [Ker03] argues that cost savings, increased reliability and enabled new services justify it. And because DSL technology will not be fully replaced any time soon, operators must make it more manageable to gain competitive edge and increase profits.

Two essential network elements for DSL are a DSL modem in customer premises plugged into a computer and a Digital Subscriber Line Access Multiplexer (DSLAM) in central office (CO) separating or mixing the voice and data signals. The DSL modem is connected to the DSLAM using twisted pair copper wire. Before the copper wire reaches the DSLAM, it goes through Main Distribution Frame (MDF) that connects the outside plant cables to CO's internal network. In the DSLAM, one port is allocated for each copper wire arriving from the DSL modem. The DSLAM separates the voice signals that go through another MDF to voice switch and data signals that are multiplexed to ISP's metro or aggregation network. When signals travel to another direction, the functionality is reversed.

Figure 7 ([Dsl02]) depicts a typical existing DSL setup. While ATM based DSLAM solutions still exist in many cases, IP DSLAMs are replacing those at the moment and at the same time the Broadband Access Server (BAS) functionality, such as enforcing quality of service (QoS) policies, is becoming a part of DSLAM's features. [Sau05]

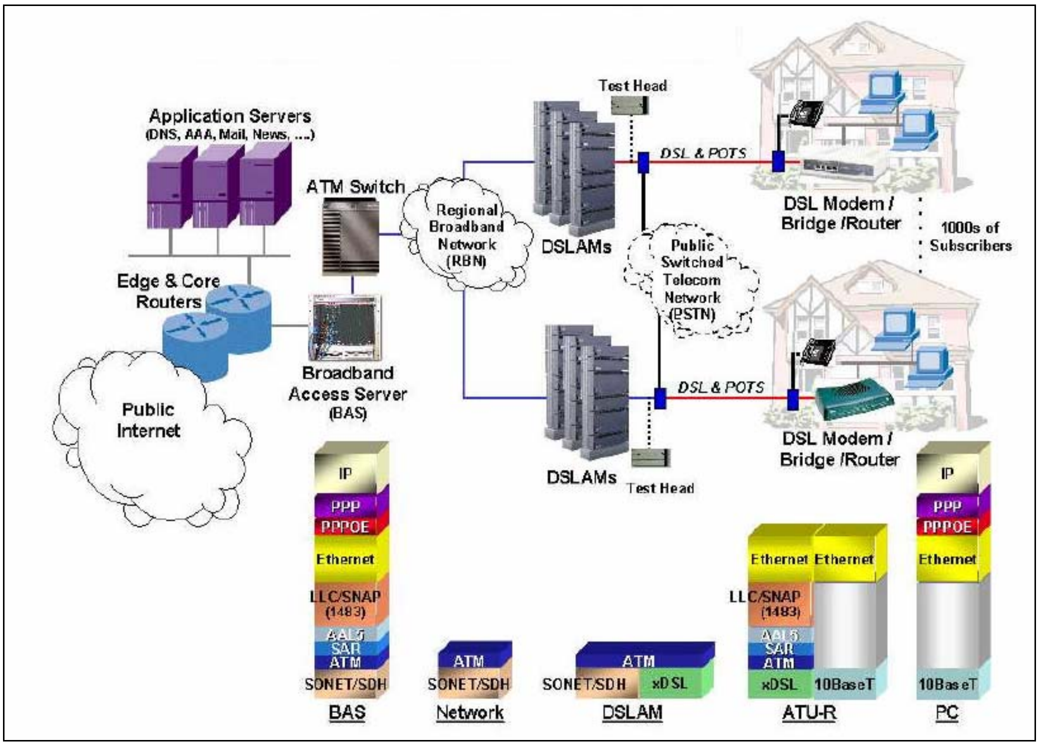

Figure 7 DSL Setup [Dsl02]

2.4.2 Cable

Another dominant local loop technology is coaxial cable TV (CATV). CATV is naturally mastered by cable television operators, while incumbent and competitive telephone operators are enforcing a combination of Digital Subscriber Line (DSL) and optical fibre technologies. CATV implementation relies on hybrid fibre coaxial (HFC) architecture that has proved to be scalable in urban areas. The latest version (3.0) of Data Over Cable Service Interface Specification (DOCSIS) defines downstream data speeds up to 160 Mbps and upstream speeds up to 120 Mbps. [WebCab] However, most current deployments and service offerings only support maximum downstream speeds up to 20 Mbps and upstream speed up to 1 Mbps. [WikiDOC]

Figure 8 ([Sub03]) shows a high-level schematic of a typical HFC implementation delivering broadcast television and DOCSIS-based data services to CATV subscribers. At the head end of the network the cable modem termination system (CMTS) multiplexes and converts signals from various sources from electrical radio frequency (RF) to an optical signal. This signal travels to a fibre node via a pair of optical fibres, after which it is converted back to RF and distributed via a single coaxial cable to the customer premises. At the customer premises a network interface unit (NIU) separates the customer network from service provider network. The RF signal is split at NIU - TV signal is directed to the TV monitor and the multimedia signal to the cable modem where it converts the multimedia RF signal to Ethernet output. The transmission mode over the coaxial cable is duplex, because the system has been designed on the assumption of asymmetric behaviour with heavy downstream traffic and light upstream traffic. The transport capacity in the HFC plant is primarily determined by the properties of coaxial cable. The CATV network delivers data services mainly for residential subscribers, where traffic patterns are assumed to be asymmetrical. [Sub03]

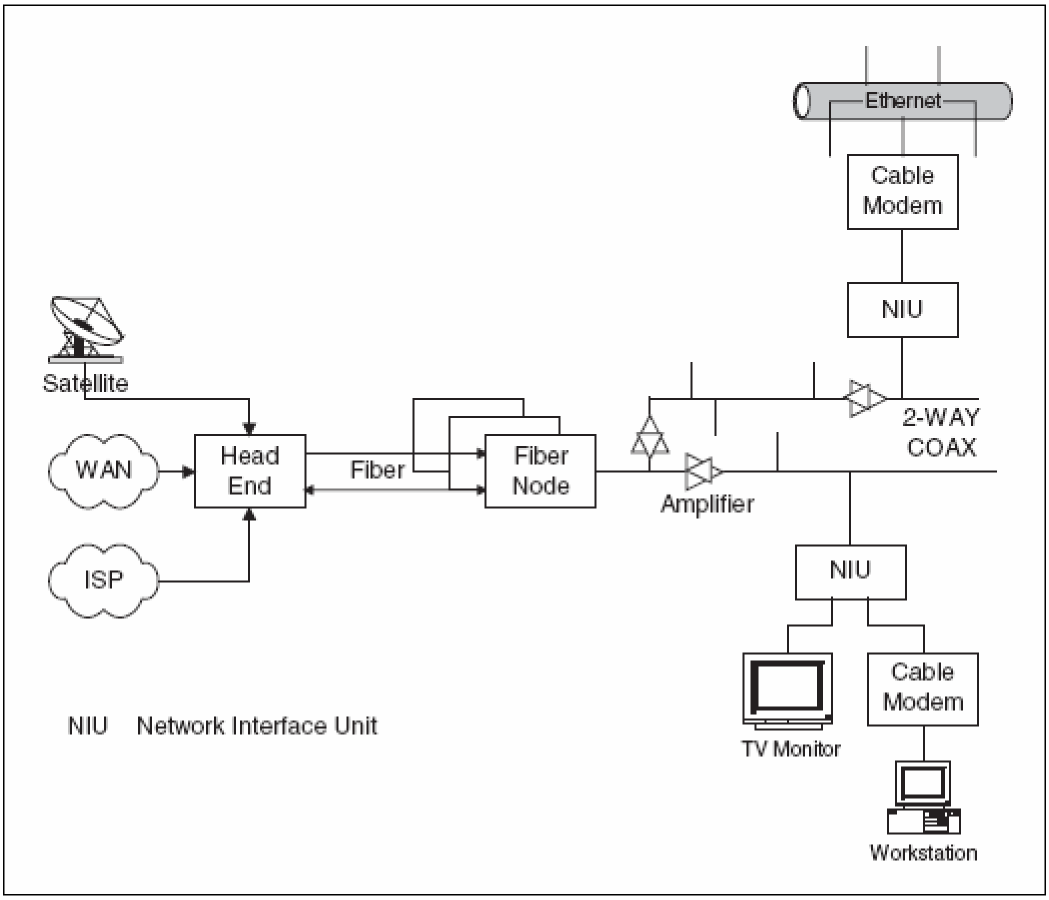

Figure 8 Cable TV Network [Sub03]

Like DSL, CATV network also needs a good network management system to be manageable and deliver NGN services. [Sub03] and [Dra02] argue that the management system should not only support basic management actions, such as activating new subscribers, but also provide dynamic bandwidth control, support for SLAs and QoS, subscriber self-service though web user interface, advanced alarm handling etc. Naturally this would require highly automated service fulfilment process. Access network provisioning is further discussed in Chapter 3.3.3.

2.4.3 FTTx

Though DSL and cable are still the dominating access technologies, some service providers have already started to deploy fibre to the home (FTTH) or other premises (FTTx). This is particularly common in green field setups where the CAPEX is reduced by deploying one network to deliver all services. While the copper wires were originally designed for voice transmission and coaxial cables for analogue video, fibre fits perfectly to high speed data transmission. Eventually, as [Kra02] states, ever-increasing traffic growth will force coaxial cable and copper wire based access technologies to be replaced with fibre based solutions.

Though fibre to home (FTTH) might not be - at least in the first phase – the most cost-efficient fibre solution, fibre to building or cabinet can offer economically profitable migration path from legacy access technologies to NGN broadband. [Mon03]

Passive optical network (PON) that uses time-division multiplexing (TDM) has so far been the most technologically and economically practical architecture for optical access technology. Wavelength division multiplexing (WDM) PON solutions have several benefits to TDM PON solutions, but the technology is currently too expensive. Hybrid WDM-TDM solution is also possible and it is presented in [Yoo06]. Either ATM or Ethernet can be used in layer 2. ATM PON (APON, defined in [ItuG.983.1]) and its two evolutions, Broadband PON (BPON, [ItuG.983.1]) and Gigabit PON (GPON, [ItuG.984.1]), were first introduced, but the latest transition has been towards Ethernet (EPON, [Ieee802.3]) based PON solutions. Extensive number of Ethernet based LANs, and growing interest in Metro Ethernet has made Ethernet a natural choice for access technology as well. [Gre04]

PON is point-to-multipoint (P2MP) optical network which means that the signal path from central office (CO) to customer premises contains only passive optical components, such as fibre, splices and splitters. PON can be build as a tree, bus or ring topology, and redundancy can also be deployed if necessary. The optical line terminal (OLT) resides in the central office and connects the optical access network to metro network. Optical network units (ONU) are located in customer premises and communicate with OLT. In some FTTx deployments, such as FTTCab (fibre to the cabinet), the ONU is not actually located in the customer premises; instead, the loop from cabinet to customer is copper. Splitter is used for splitting the signal from OLT to ONUs, which means that each signal from OLT is actually broadcasted. This is convenient for IPTV and other broadcasting services, but on the other hand decreases available bandwidth per customer and weakens security and fault tolerance. However, as [Yoo06] states, in WDM PONs these issues are alleviated, because wavelengths can be allocated per customer, allowing virtual point-to-point connections and increased bandwidth. Although actual point-to-point (P2P) connections from CO to customer premises are also possible, they are currently rarely used because they require significant outside plant fibre deployment and connector termination space in CO. [Kra02] FTTx technology is under constant development and it will take time before it replaces current, inferior access technologies. Simplified picture of FTTH architecture is presented in Figure 9.

2.4.4 Wireless Access

Wireline infrastructure is generally more expensive and time consuming to deploy than a wireless one, and therefore requires higher density of population to be profitable. Rural areas and developing countries frequently lack optical fibre or copper-wire infrastructures for broadband services and installing the necessary equipment would be too expensive for the service provider. Therefore many residents do not even have the possibility to obtain broadband service. Wireless approaches could solve this problem, and especially WiMAX (worldwide interoperability for microwave access) has gained a lot of momentum recently. Other possible technologies for wireless broadband include technologies such as 3G mobile technologies (UMTS, Universal Mobile Telecommunications System) and WLAN (Wireless Local Area Network). [Vau04] However, from the management point of view these wireless broadband alternatives resemble current mobile networks. Subscriber and service information is stored in service centres and there is no need for direct resource allocation. The service fulfilment process is easier to define, and therefore this study does not cover the service fulfilment process of wireless access.

2.5 Summary

The service provider’s network consists of three parts: access, metro (sometimes referred to as *edge*) and core (*transport*) network, which are illustrated in Figure 9. Access technologies are presented on the left, metro environment in the middle and IP/MPLS core network, containing application servers, on the right. Before the service provider is able to offer NGN services it must have functioning end-to-end management capabilities. Providing end-to-end QoS at the network has been a major technical issue for service providers seeking revenue sources other than network connectivity services.

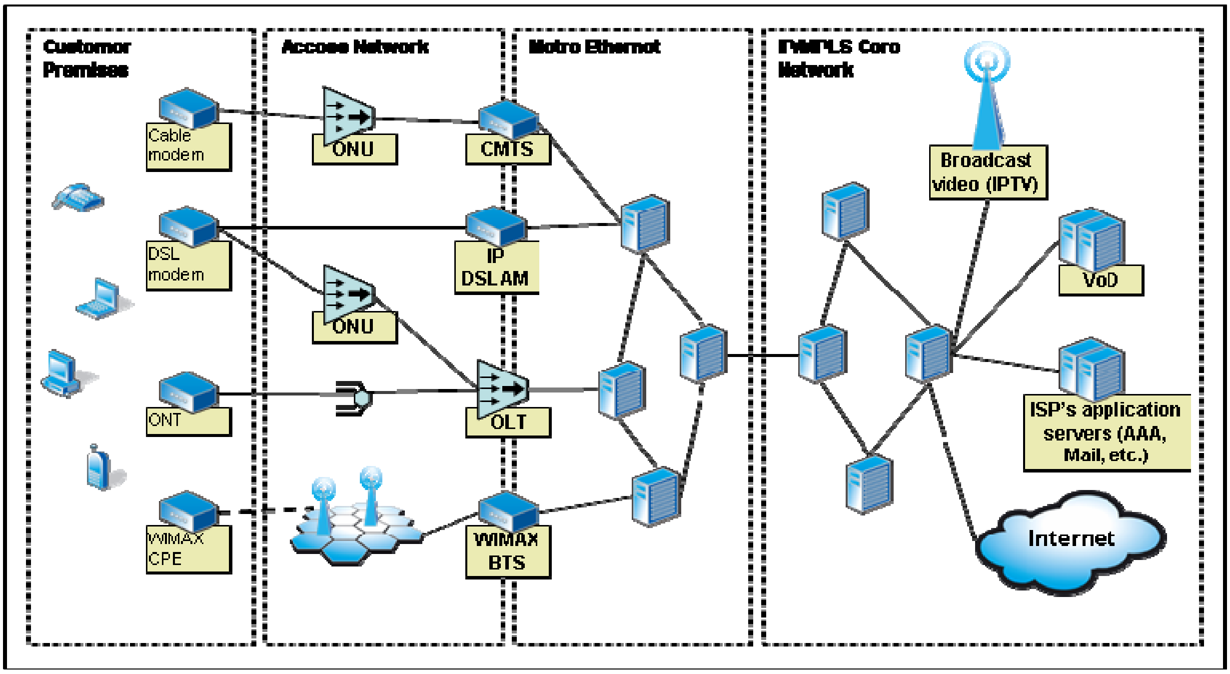

Figure 9 NGN Network Architecture

The access network is responsible for transferring the data between customer equipment and metro nodes. In access, the network can be shared between managed service traffic and best effort traffic, but this requires differentiated traffic handling. The differentiation mechanisms can be based on simple priority handling, or more sophisticated ones, such as virtual tunnels (VLAN etc.) supporting QoS and security.

Metro network contains service intelligence and performs the mapping of QoS requirements between the access network and the core network, allowing different traffic handling and route control for best effort and managed service traffic. This requires more sophisticated processing in metro nodes, because each of the incoming packets from the access network should be mapped to the proper tunnels in the core (and vice versa) based on the desired QoS level and destination address (see Figure 10). Complexity increases even more, if it is necessary to process each packet to identify source address, application type, destination address, and other information required for proper routing and traffic management. The metro network can also contain value-added service features that are best provided at the metro locations (e.g., managed security, content filtering). Some NGN services might also require controlling not only the access network, but also customer premise equipment.

The managed core network will consist of a set of MPLS (LSP) tunnels that provide simple but high-throughput transport of packets between metro nodes. In core, the data transmission must be fast and therefore there is no time for similar functions (such as mapping the tunnels) as in the metro. [Lee03]

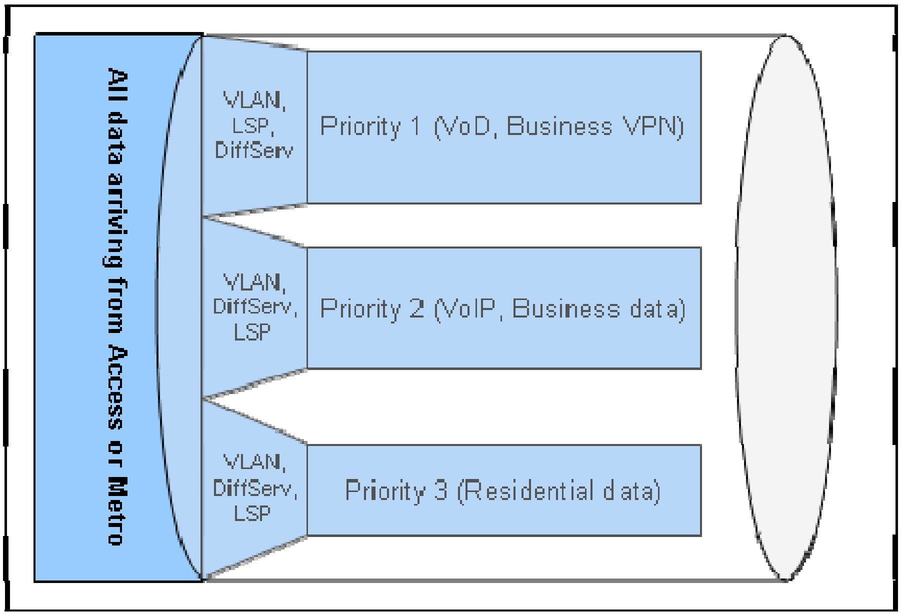

Figure 10 Data Prioritisation and Tunneling

To manage end-to-end connectivity effectively, service providers need operation support systems that automate most of the complex management procedures. In the next chapter we will examine service provider's operational environment and concentrate especially on the service fulfilment process.

3 Service Provider’s Operational Environment

Next generation packet-based networks are much more complex than networks in the circuit-based voice world. Configuring end-to-end data connection requires selecting between several different routing configurations and policy rules. Technologies and protocols have multiplied, and while the traditional wireline networks were mainly implemented using a technology from one manufacturer (such as Lucent or Cisco Systems), now network elements from several vendors are most likely present. [Dit06] As a result, for many emerging technologies the complexity and cost of management either outweigh the technological benefits or force service providers to overengineer their networks, instead of deploying bandwidth-saving quality of service techniques. [Ver02]

In this chapter it will be first examined what the most significant stakeholders are when management of NGN services and network is discussed, after which the general framework and requirements for NGN Operation Supports System (OSS) architecture are presented. Then, the service fulfilment process is studied, concentrating first on the network resource management, and after that, on service management.

3.1 Stakeholders

Several different stakeholders exist when NGN networks and services are discussed. First there are the Internet Service Providers (ISP), or service providers in general, offering access to Internet and related services. Traditionally ISPs were run by phone companies, but nowadays other players also exist. Cable companies have become Multiple Service Operators (MSO), providing data and voice services in addition to cable TV service. Competitive start-up operators, who purchase the last mile from network operator, have also emerged. ISPs can be divided into three Tiers:

- Tier 1 ISP (9 in total, such as AT&T and Level 3) connects to the entire Internet via peering, i.e. Tier 1 ISP does not purchase transit from anyone. In order to be a Tier 1 a network must peer with every other Tier 1 network. Tier 1 ISP primarily sells service to organisations with large bandwidth requirements, such as telecom carriers, cable TV operators, universities, web hosting companies, and to other, smaller ISPs, often known as Tier 2.

- Tier 2 (British Telecom, France Telecom, TeliaSonera etc.), ISP who peers with other networks, but who still purchases IP transit from Tier 1 to reach the complete Internet. Tier 2 ISPs are commonly national service providers.
- Tier 3 ISPs purchase almost all IP transit from other networks (typically Tier 1 or Tier 2 networks) to reach the Internet, and do not necessary own the last mile. [Nor02]

Although the definitions for the Tier hierarchy often vary, the presented layering offers a good way to categorise ISPs. Especially Tiers 2 and 3 are under evaluation in this study, because they have large customer base (consumers and enterprises) and therefore automated service fulfilment is an obvious requirement. Naturally, mobile operators also belong to service provider category, but mobile networks are not discussed in this study.

Network equipment vendors are a second very influential group. They develop new technologies, and it is in their interest that service providers purchase new, more advanced technologies. However, as already mentioned, the technological advance has been so fast and diverse that network management has become very complex.

Therefore, standard bodies dealing with the network management issues play a very important role. But because there are several different standardisation bodies, their activities and interests often overlap, causing competition and increasing the uncertainty between network equipment vendors. Standard bodies also see things from different perspectives due to their history - while IETF and DMTF have an IP centric view, ITU, TMF, ETSI and 3GPP are very telecom (circuit) oriented. Many industry consortiums have also emerged, such as Metro Ethernet Forum, MPLS Forum, DSL Forum and FTTH Council, making the organisational structure even more fragmented and harder to perceive. Standardisation issues are further discussed in Chapters 3.3.2 and 3.4.3.

The complexity of modern network environment has created a versatile service industry operating between service providers and network layer. System integrators, such as IBM and Accenture, manage the overall architecture and integrate service providers' systems to network. Operation Support Systems (OSS) vendors provide more specific systems e.g. for collecting the billing records from the network and mediating them to service provider's system (hereafter called mediation), and for activating a new subscriber to the network when an order from the service provider's system is received (hereafter called service fulfilment).

3.2 Operation Support Systems

Operation Support Systems (OSS) enable service providers to cost-efficiently manage their customers and provide significant benefits through higher productivity, fewer errors, flow-through automation, improved utilisation and lower churn. Service providers are trying to minimize their operational expenditures (OPEX), and become *lean operators*. Process automation, system integration, data integrity, customer self-management, flexible service delivery platforms and interoperable Commercial off-the-shelf (COTS) products are key features for service providers' operational infrastructure. With cleverly designed and flexible OSS architecture service providers are able to introduce new services and features within days instead of months, shorten the time-to-revenue, easily respond to business changes and gain competitive edge. [May03]

TeleManagement Forum (TMF) ([WebTMF]) has developed Next Generation Operational Systems and Software (NGOSS) framework ([NGOSS06]) for the NGN telecommunications management. Other models also exist (they will be discussed in Chapter 3.4.3), but TMF's NGOSS was chosen here due to its wide acceptance and clear presentation. Important part of NGOSS is Enhanced Telecom Operations Map (eTOM), also defined in [ItuM.3050], that describes all enterprise processes required by a service provider. It suggests potential boundaries of software components and describes the required functions, inputs and outputs for OSS products. eTOM divides the service provider processes to three major process areas: strategy, infrastructure and product coverage planning and lifecycle management; enterprise management covering corporate or business support management; and operations covering the operational management. Figure 11 presents these process areas and shows the layering inside them.

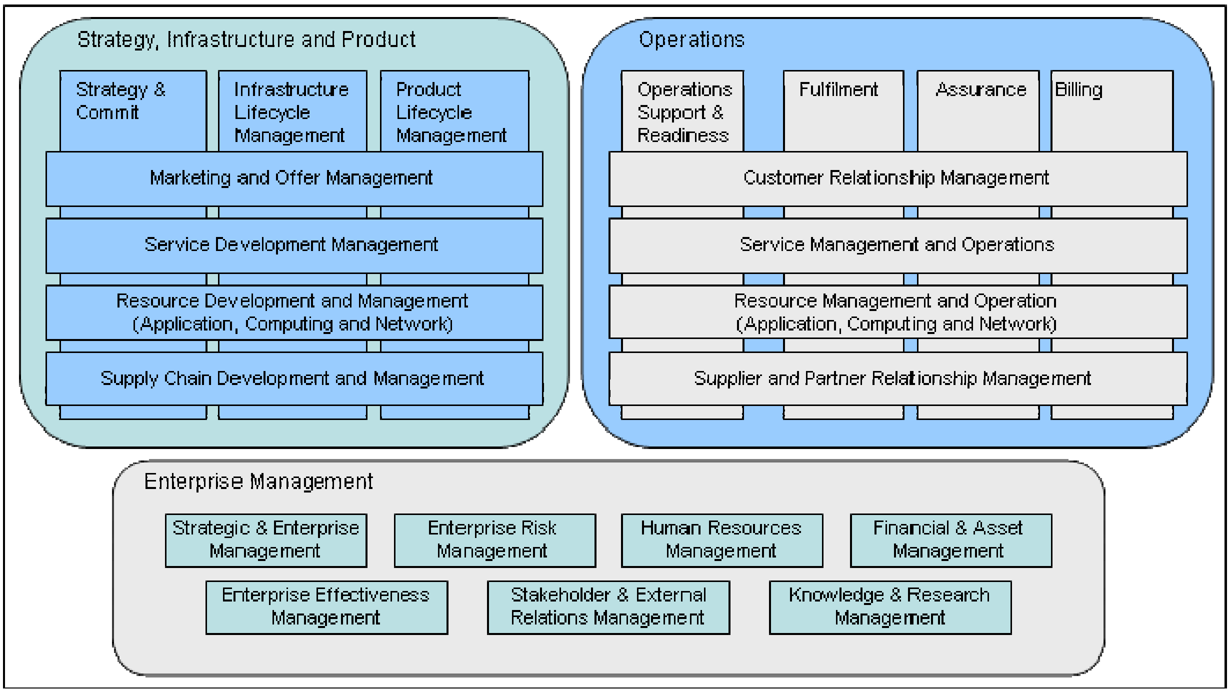

Figure 11 Enhanced Telecom Operations Map (eTOM) - Overview

From an OSS vendor's point of view the most interesting process area is operations, consisting of fulfilment, assurance and billing. In this study we concentrate on fulfilment, and especially on its two middle layers: service and resource management and operations. Order handling (management) that belongs to top layer in fulfilment is also interesting, because it plays an important role in the service fulfilment solution for broadband. Resource data collection and processing plane in between of 3rd and 4th layer of the fulfilment stack is also a necessary part of service fulfilment solution. [eTOM06] The different OSS modules for service fulfilment are further analysed in further chapters.

NGN Requirements for Operational Environment and OSS

Service providers are facing more and more competition from non-traditional players such as cable companies and alternative players (Google, Skype, Joost etc.) while their average revenue per user (ARPU) and profit margins are decreasing. In addition to saving costs by replacing the manual work with automated systems, service providers are also forced to search for new sources of revenue. According to [Etsi05] it is generally accepted that the future revenue growth is achieved by increasing the number and types of services offered to customers. Requirements for faster time-to-market of services and automation enabling OSS increase the investments on COTS solutions, because service providers do not have the time and money to develop their internal solutions. However, implementation and productising of NGN OSS solution is not a trivial task, because the mix of services and technologies, both legacy and NGN, is so wide. And as [Etsi05] states, the lifecycle of services and technologies is shortening all the time, creating a requirement for very open and extendable systems.

[Etsi06] and [M.3060] list requirements for service provider's operational environment. Requirements that concern the topic of this study and are relevant are presented next, while the full list can be viewed through the referred sources. First the requirements for network resource management are presented, and second, the requirements for service management.

Requirements for Network Resource Management

- Ability to manage NGN physical and logical resources, including resources in the core network, access networks, interconnect components, and customer networks and their terminals. This allows compiling an abstracted view on resources that hides the complexity and multiplicity of technologies and domains in the resource layer.
- Ability to have automatic and dynamic allocation of network resources and automated end-to-end services provisioning with minimum amount of manual work. This requires consistent cross-technology management interfaces on both service and transport elements, allowing an integrated view of resources.
- Ability to exchange management information across the boundaries between network environments: the boundary between the transport and service layers, the boundary between control and management planes and the boundary between administrative domains.
- Improved resource resilience through self healing networks and protection switching. If this cannot be implemented in network level, highly dynamic service fulfilment solution can be utilised.

Requirements for Service Management

- Ability to manage NGN service resources independently from the underlying transport resources. This allows service providers to reduce the time frame for the design, creation, delivery, and operation of new personalised service offerings.
- Centralised service information base, enabling different OSS components (e.g. billing and service fulfilment) to access the coherent service information.

- Provide management capabilities that will enable end-user service improvements including customer self-service, reporting faults and online billing reports.
- Proactive management capability, particularly for fault resolution and SLA management and monitoring.

These requirements must be considered when designing service fulfilment solution NGN networks. Although many of them are quite abstract, they give a good general view on the demands for NGN network management.

3.3 Network Resource Management

Service fulfilment refers to the complete process from receiving customer order (e.g. for broadband or business VPN) to activating and testing the service in the network. The main issue is most commonly how to extract the technical details from the service and activate the service in the network. This chapter will discuss the resource management, i.e. how the serviced are activated in the network, while the next chapter covers service management, i.e. how to define new services and extract the technical details from them.

For the resource management we must define two separate concepts: network provisioning and service activation. Service activation and network provisioning are often referred to as synonyms, but basically they are two different things: provisioning means modifying the network and infrastructure creating, modifying or removing a subscriber’s service, while activation stands for modifying subscriber account records to create, modify or remove a subscriber’s service. For example, opening a subscriber’s DSL account is around 50% provisioning and 50% activation, while opening a subscriber’s mobile account is practically 100% activation. DSL case consists of configuring routing information and selecting ports on a DSLAM and possibly on BAS (provisioning) and setting a subscriber account on an email server (activation), while mobile case consists of configuring subscriber information, for example, into Home Location Register (HLR) and Voice Mail System (VMS) (activation).

Service activation is closely related to mobile networks, where subscribers and services are activated in “service centres”, such as HLR. The activation process is rather simple in these cases, because no network resource is actually allocated to a customer, and thus no information about available network resources is required. Network provisioning, on the other hand, is largely associated with broadband and IP services because there is a direct allocation of network resource to a customer. Network provisioning process is usually much more complex and might also require some manual steps, such as installing new infrastructure or connecting subscriber line to a port. This is why the network provisioning process is usually supported by order management system, which controls and tracks the service delivery. Network inventory management system is also essential, because the provisioning system must know which network elements (routers etc.) it should provision and whether both physical and logical resources exist. Figure 12 shows the different pieces of service fulfilment according to eTOM model. While in the mobile case the service fulfilment occurs mainly in the Service Management and Operations layer, in fixed networks the Customer Relationship Management, and Resource Management and Operation layers contain extensive functionality. It should also be noted that although we often refer to service activation, service fulfilment is actually involved with the entire life-cycle of the service, including any subsequent orders to modify or disconnect the service

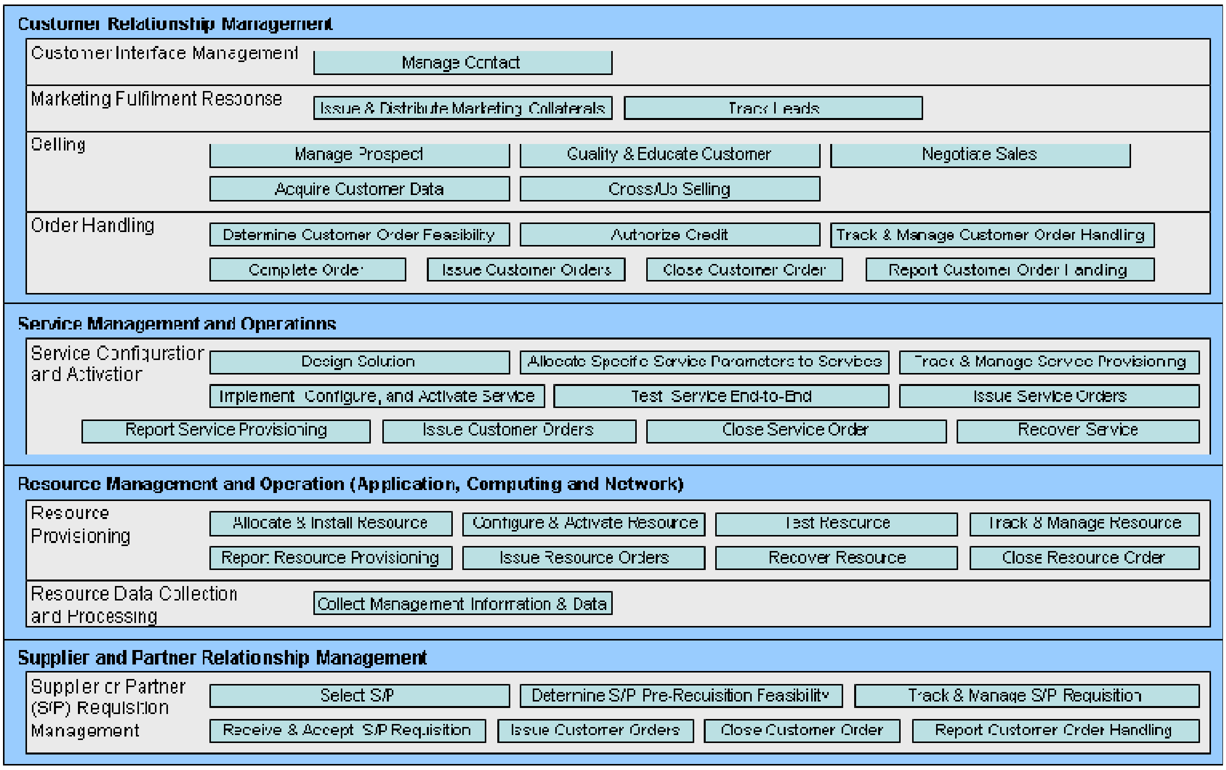

Figure 12 Enhanced Telecom Operations Map (eTOM) - Service Fulfilment

Overall, it can be seen that a service fulfilment process that requires network provisioning, can become quite complex to define and manage. Several OSS modules must be able to communicate with each other before the service request can be fulfilled. However, these challenges are generally recognised and several NGOSS based interfaces for OSS-to-OSS communication are standards by TMF. These interfaces include OSS/J (OSS through Java), MTOSI (Multi-Technology Operations Systems Interface), MTMN (Multi-Technology

Network Management), IPNM (IP Network Management) and CO-OP (Co-operative OSS Project). Although especially OSS/J has gained some momentum lately, OSS-to-OSS interfaces are still mainly implemented on the case-by-case basis.

In the following subchapters we will continue studying the basic characteristics of network provisioning process, and try to define some general guidelines for implementing an NGN service fulfilment solution.

3.3.1 General Requirements for Network Provisioning

Service providers are struggling with accuracy of the network provisioning. In order to successfully deliver a service, several general conditions must be met:

1. allocated resources must exist,
2. resources must not be allocated to other services,
3. physical location of resources must be known, and
4. physical and logical connections between resources must be known.

Any mistakes may result in delays in the activation of the customer services or, even worse, accidentally turning off another customer’s service. Reservations, i.e. future allocations of resources, must be also managed. The provisioning process and requirements for different networks are discussed in the following chapters.

Another key issue is the translation of what the customer buys to what the network delivers. It is essential that the network capabilities are accurately recorded so that new product definitions can use what the network is already able to deliver. This will be discussed in Chapter 3.4.3.

Failure to meet these challenges makes the service fulfilment process inefficient and leads to increasing operational expenditure (OPEX):

- increased use of manpower in the manual steps of the process,
- need to roll-back from mistakes (often very expensive), and
- poor quality of inventory information post-activation, leading to a lower quality in service and network assurance and maintenance.

The capital expenditure (CAPEX) will also increase, because

- inefficient use of existing equipment, due to lack of knowledge on resources, leads to unnecessary procurement of new equipment.

In addition to extra expenses the quality of customer experience will drop due to

- delays in delivering the service, and
- customer perceiving service provider's disorganized service delivery process.

Eventually the market share will decrease, because rapid and reliable service activation is a key to customer satisfaction - committed delivery time is often one of the differentiators for a service. Therefore, it is vital for the service provider to have a well managed service fulfilment process, and a good service fulfilment OSS plays an important role in this.

3.3.2 General Issues with Network Provisioning

In the network level, network provisioning means router configuration. Router configuration has been a manual process in past, and in many occasions, even today. Manual configuration is an expensive and error-prone process, but although these shortcomings are admitted, manual configuration has been considered as the best possible option. [Cal04] lists the reasons why the automation of router configuration is seen as a very challenging task.

First of all, routers offer very high degree of configurability. Routing protocols (OSPF, BGP, MPLS etc.), interfaces, access control lists, QoS mechanisms, and services such as Simple Network Management Protocol (SNMP) and Network Address Translation (NAT) must be properly and consistently configured by network administrators before the router and network can reliably work.

Second, router configuration is done using complex, low-level configuration languages. Router vendors have their own proprietary configuration languages, and in most cases executing several incremental commands to achieve some higher level task is required. Most routers are configured through command line interface (CLI), which is feasible for manual configuration, but problematic for automating the process. SNMP on the other hand was developed for system-to-system interaction, but it is mainly used for monitoring. Many routers also implement standards based Management Information Bases (MIB) that can be used with network management protocols to configure and monitor router functionality. However, most SNMP and MIB combinations are only used for monitoring, and not all MIB modules are even writable. Due these issues and other issues described in [Rfc3535], IETF formed a working group ([WebNetconf]), focused on developing an XML based configuration protocol that would eventually replace vendor-specific configuration protocols. This new protocol, NETCONF ([Rfc4741]), was published in December 2006, and for example VLAN data modelling for NETCONF ([Iij07]) has been already started. Naturally, it will take time before network vendors start implementing NETCONF support for their routers, but the consensus should exist, because all main vendors were able to participate in defining the requirements ([Sch03], [Rfc3535]).

Finally, router features are under constant development. New features (such as MPLS and BGP extensions) bring new configurable options, requiring data models, languages and configuration tools to be easily extensible. For example CLI commands and especially output have been prone to change with new router operation system releases. This is acceptable for humans, but disruptive for an automated provisioning system. Relatively easily extensible XML based NETCONF tries to also address this problem.

However, although manual configuration has been the main trend, [Cal04] argues that moving beyond manual configuration is crucial, because the manual process is too error-prone, leading into network outages, degradation of performance and security vulnerabilities; and expensive, caused by costly mistakes and delays in enabling services for new users. Manual configuration also requires large number of skilled engineers, which are expensive to hire and train.

NETCONF is not the only attempt to make the NGN networks more manageable. ITU-T has formed a study group ([WebItuSg4]) focusing on NGN management issues, and NGN Management Focus Group ([NGNMFG07]) is acting as a coordinator between different standard bodies, stimulating them to fill gaps and resolve harmonisation issues. The group follows work and specifications done by 3GPP, ATIS, DMTF, ETSI, IEEE, IETF, ITU-T, MEF, OASIS and TMF.

3.3.3 Access Network Provisioning

Access network provisioning is naturally almost always necessary when new services (e.g. broadband) are activated for a new or existing customer. Access network provisioning is in the most cases the most challenging and time-consuming step in service fulfilment process. [Dsl02] lists a few vulnerabilities of the DSL provisioning process and systems, but most of them also apply to other access technologies:

- Labour intensive process that consumes extra resources (time and money).

- Error-prone process, especially hand-offs of information between operational entities causes problems.
- Manual network provisioning causes delays in the process.
- Many in-house legacy systems instead of a converged system that controls everything.
- Lack of visibility into partner systems and networks.

Chapter 2.4 introduced different access networks and their elements. Provisioning of different access networks has been discussed in literature: DSL ([Dsl02], [Ker03], [Bul06], [Kim06]), optical ([Tay02]) and cable ([Dra02], [Sub03]). Without an adequate support of the service fulfilment system, the service provider will not be able to meet customer expectations in highly competed markets. Essential part of access network provisioning is network inventory system, containing the information about the available resources. After the resources are located, the provisioning can be done using the network provisioning system. However, it should be noted that access network provisioning often requires an order management system, and some parts of the service fulfilment cannot even be automated. For example, in some cases it might be necessary to install new equipment before the service order can be fulfilled. This process requires at least workforce management, making the service fulfilment process more complex.

3.3.4 Metro and Transport Network Provisioning

Next generation IP services rely on robust underlying transport network that mixes several technologies. In this study we have mainly focused on Metro Ethernet and IP/MPLS transport network implementations, but a first-class transport provisioning system should also be able to handle older technologies, such as Frame Relay, ATM and SONET/SDH.

There is a demand for automated, efficient and easy-to-use management systems for Ethernet and IP/MPLS network services. Complexity of next generation network infrastructure introduces several challenges to management systems. Demanding enterprise applications (VoIP, videoconferencing, SAN extensions etc.) have high QoS requirements, and an IP/MPLS network running these and other network services - such as MPLS VPN and VPLS - must adjust to those. QoS is guaranteed both by the provider core and the provider edge. The provider core guarantees the necessary bandwidth for services in all situations (also during network congestion and failure) and the provider edge offers class-based treatment of flows by scheduling and discarding the packets based on the service. Therefore, guaranteeing the subscribed QoS throughout the network means that the entire path (provider edge - core - provider edge) must be provisioned consistently. Varying access and aggregation technologies of different customers make the task even more complex. [Bel04]

From the service fulfilment point of view it should be noticed that most of the network provisioning occurs on the edge of metro or core network, because the core itself does not separate the traffic between different subscribers. The most common network provisioning actions in metro and transport are most likely related to mapping subscriber traffic to specific tunnels. [Ghe06] thoroughly explains MPLS VPN (also in [Hal01], [Kol01]), VPLS and LSP configurations, and VLAN configurations are presented in [Huc02]. Although configurations are Cisco Systems specific, they describe the general process well. General requirements for MPLS network management system are discussed in [Sha05].

[Dit06] argues, that although network equipment vendors offer network management system for their own equipment, service providers should not rely on vendor- or technology-specific solutions. Instead, all provisioning actions should be managed through the same system. Only this way service providers are able to establish and maintain quality of service (QoS) across the different vendor and network layers to meet customer expectations and their service level agreements (SLA). An accurate inventory system of transport resources is a mandatory part of the provisioning system, because the system must keep track of all physical and logical resources. The system must also provide off-the-self network element interfaces and be automatically synchronised with the network, in order to be easily upgradeable and able to maintain accurate network state.

However, modelling of the whole metro and core network is not mandatory for service fulfilment purposes. When modelling the network, it should be considered what information is necessary and how extensively the interfaces to network elements are implemented. Management actions that occur only rarely can be executed directly to the router, and not through service fulfilment system. Also, some network elements are managed by a vendor specific network management system (NMS). If the NMS offers an open interface, it should be utilised instead of implementing interfaces directly to routers.

3.3.5 IP Services Provisioning

With IP Services we refer to advanced services that require both service activation and network provisioning. Access and transport network provisioning is mainly done for establishing IP connectivity, but after that is successfully achieved, the value-added services can be activated. As we defined earlier, this part is often called service activation. Service activation is simpler than network provisioning, because the information about location and availability of equipment is not necessary, and thus no network inventory is required. Instead of routers and switches, services are activated in service centres or application servers, such as email and Video on Demand (VoD) servers, and Softswitches (to activate VoIP, discussed in [Pra05]). However it must be remembered that before for example an IPTV order can be fulfilled, the availability of network resources must be checked. Also, for IPTV, the service provider might use separate VLANs for transmitting the channels, which means that the customer should be assigned to specific VLANs. This way, as stated before, the activation of new IP service becomes a combination of network provisioning and service activation.

IP Multimedia Subsystem (IMS) [Ims06] defined by 3GPP [Web3G] is often referred to as an essential part of NGN network and services. The IMS has much in common with mobile network activation. For example in IMS the intelligence and services are centralised to Home Subscriber Server (HSS) and application servers, making the scenario pretty much similar to current mobile networks where intelligence is located in network elements, such as HLR (corresponds to HSS), and therefore the service activation process can be rather easily defined. [Nie02]

3.3.6 Service Fulfilment OSS Market Forecast and Current Trends

In the past most service providers developed their Operation Support Systems (OSS) applications in-house, but the recent shift has been towards COTS products offered by hundreds of different OSS vendors. In the early 1990s OSS applications were 90% in-house developed, but in 2002 the number had already decreased to 60% [May03]. Although in-house developed solutions can initially be faster and cheaper to roll out, there are unavoidable weaknesses with this alternative, such as expensive maintenance and introduction of new services, and lack of already implemented element libraries and interfaces.

Service activation was one of the first OSSs available as COTS product and is still a very profitable OSS segment. [Ban06] estimates a 27.5% increase in Compound Annual Growth Rate (CAGR) between 2006 and 2010, but [Gol07] gives a little more cautious estimation and suggests a 12% CAGR between 2006 and 2011. For service fulfilment in general (as a combination of order management, network inventory management, activation and traffic engineering) [Gol07] estimates a 9% CAGR, while the spending will grow from $1.86 billion to $2.85 billion. Overall, it can be seen that markets are still growing, and the maturity phase has not been achieved yet. However, competition is also increasing because vendors from other OSS/BSS categories are entering the market via product development, partnerships and strategic acquisitions. Current market situation will be analysed in Chapter 5.2.1.

There are several drivers for growth in service fulfilment OSS. According to [Ban06], service convergence will continue increasing complexity in service activation process and therefore speeding up the process of integrating fragmented pieces of order management and activation together. Configuration and network management solutions will be integrated with service activation solutions and service providers expect more network-facing capabilities. Discovery, reconciliation and some aspects of network configuration are becoming a very important part of activation with the logical inventory management product offering real-time information of network and device utilisation, logical service paths, network traffic and network topology.

Service providers need to be able to analyse, monitor and measure network, and therefore service fulfilment must also handle with network load and traffic engineering issues. The status and performance of services must be constantly monitored when they are delivered over highly dynamic next generation network infrastructure. Service providers will not be able to offer and earn money from finely-tuned Service Level Agreements (SLA) unless their network can dynamically adjust to varying situations by, for example, automatically reconfiguring or creating LSPs to satisfy SLA. This kind of solution will require either tight integration between service assurance and service fulfilment OSS, or introducing some features from service assurance solutions to service fulfilment solution. [Bel04]

From the pure service activation point of view, service providers expect more real-time provisioning, because they want to be able to offer a possibility for their customers to self-manage their services. Consumers and businesses demand unified communication capabilities over different networks, which also increases the expectations for service activation platform. IMS and growth in VPN and other value-added services ensure the demand for network-facing service activation solutions by service providers. Although VoIP, for example, has not yet fulfilled all its expectations, it must be remembered that if several service providers start offering low-cost voice calling services, a well-functioning COTS service activation solution will provide the necessary competitive edge. [Ban06]

3.4 Service Management

Service fulfilment OSS should provide a service activation that is as automated as possible, but there are other important features that first-class solution should also offer. Since bandwidth has become a commodity, service providers are looking for new sources of revenue from selling services. However, creation of new services has been much simpler on paper than actually in the network, due to the deficiencies in service fulfilment systems. Introducing a new service might require anything from a marketing person dragging and dropping service packages together and forming an immediately sellable product bundle, to a legion of programmers configuring the service provider's legacy system. Naturally the former sounds like a better and more desirable alternative, but for several reasons it has not been the real-life scenario so far. [Sub03]

In the next chapters it is discussed how to make services more manageable and enable faster and less expensive roll-out of new services.

3.4.1 Service Trends

Service providers, both fixed and mobile, generate most of their revenue from voice, but the business is decreasing all the time. The industry is experiencing a shift from voice to data services, providing access to application and content. The number of services is also constantly increasing, leading into need for mass customisation, better market segmentation and more complex tariff logic. [Etsi05] Especially mass customisation is interesting from service fulfilment point of view, because it requires good tools for not only creating service bundles, but also for activating the services in the network level. While this study has mainly discussed the most common services, such as VPN, IPTV and VoIP, more innovative services can also be considered. For example [Etsi06] lists over 20 different NGN services, practically all of which would require a rather complicated service activation in the network. Before the service provider is able to offer these services to large masses profitably, its service fulfilment system must allow rapid and automated service activation.

3.4.2 Service Level Agreements

One of the main drivers for Next Generation Networks (NGN) is the new services that they enable. These advanced services create new requirements for the network and typical best-effort Quality of Service (QoS) is not enough. However, managing QoS in NGN networks is not a trivial task, because all kinds of different traffic (data, voice, video etc.) will run on the same network and each of them has their own unique requirements. Providing bandwidth is not enough - other attributes, such as loss, delay and jitter, must also be considered. Service Level Agreement (SLA) and its technical part, Service Level Specification (SLS), define the QoS requirements that the customer (e.g. enterprise or another service provider) is expecting and the service provider must fulfil. Customers not only demand provision of expected QoS, but also reliable measurement of QoS. SLAs allow service providers to profit more from their customers, but it also raises a question, how to optimally utilise their increasingly complex network? [Mar02a]

For example, when Metro Ethernet technology is applied, it raises a question of how to share the infrastructure. In case of legacy TDM deployments, there is no such issue, because a circuit is allocated for each separate customer, and this isolates traffic from other customers' traffic. SLA can be then approved based on the purchased circuit. Defining SLAs becomes more difficult in Metro Ethernet environment, because packets from different customers are multiplexed over the same pipe (bandwidth is shared), and traffic is isolated from other customers' traffic only logically. Guaranteeing QoS requires several functions to be well-defined: identifying the customer's traffic, identifying and enforcing the service given to the customer, allocating certain bandwidth to specific customer, moving the customer's traffic transparently between different locations in case of transparent LAN service, scaling the number of customers and deploying VPN service that offers any-to-any connectivity for the same customer. [Hal03]

Multi-vendor, multi-domain and multi-technology networks complicates the end-to-end SLA management even more, and creates demand for advanced fulfilment, assurance and billing functions. In fulfilment the main issues are resource allocation, request handling and admission control, i.e. receiving a resource request and finding out if can be fulfilled; allocation management, i.e. communicating resource reservations with network elements; and interoperability with other OSS systems, such as assurance, so that resources could be automatically reserved according to rapidly changing network circumstances. By managing these functions efficiently service providers can enforce the confidence that customer is experiencing towards NGN services, and thus generate competitive edge. [Mar02b]

3.4.3 Technical Presentation of Service

The reason why managing network service can be quite complex is fairly clear. For example activating a VPN service in service provider's network might require the network administrator to configure dozens of discrete network elements. A simple solution would be to provide a flexible way to manage large networks as single entity rather than thousands of separate elements. However, network topologies and technologies vary a lot, making the network modelling very difficult. And although network equipment vendors might be capable of this modelling work and centralise the network management in network management system (NMS), the multi-vendor environment is still an undeniable challenge due the lack of dominant network management standards (discussed in Chapter 3.3.2). For this reason the network operations that occur often and require costly manual work should be automated in a multi-vendor network using OSS. Complex and rarely occurring configurations can be still executed through the vendors' network management systems or by sending commands directly to network elements.

There have been several attempts to overcome the issues described in Chapter 3.3.2 and make network management and provisioning more controllable. The first step is to separate business level from technology level. The concept is quite similar to how SLA and SLS were defined in the previous chapter. For example VPN can be constructed either using VPLS or MPLS VPN (see Chapter 2.3.3) technology, and thus it should be possible for network administrator to simply select *activate VPN between these points*, no matter what the underlying technology is.

In the early 2000s Policy-Based Management (PBM) was seen as a solution for separating business and technology levels and making the network management and provisioning easier and more automated. IETF and DMTF jointly developed an information model for representing policy information, which was known as Policy Core Information Model (PCIM) and defined in [RFC3060]. Policy (as defined in [Rfc3198]) was to be used to configure a service in a network or on a network element, invoke its functionality, and coordinate services in an inter-domain or end-to-end environment. [Rfc3060] stated that policy classes and associations defined in PCIM were sufficiently generic to allow them to represent policies related to anything, but it was expected that their initial application would be for representing policies related to QoS (DiffServ and IntServ) and to IPSec. [Ver02] and [Hon02] describe PBM in general and discuss about service management issues, while other studies concentrated on more technology specific issues: IP VPN ([Guo03]), IP DiffServ [Fle02], MPLS ([Bru01]) and optical networks ([Faw04]). Despite the initial interest, there has been lack of actual Policy-Based Management applications. PCIM is very QoS centric model and therefore fills the network modelling needs only partly.

Although Policy-Based Management did not gain as much interest as originally expected, the general idea of the model can be recalled: service should be separated to high-level business level and low-level technological level. Business level defines what the customer buys, technology level how network delivers the service – in the same manner as how SLA defines the business terms and SLS technical terms. Two standard bodies have been developing models for describing these entities. TeleManagement Forum's (TMF) Shared Information/Data (SID) is the NGOSS information model, providing an abstraction and representation of the entities in a managed environment from a business as well as a systems perspective ([WebSid]), and Distributed Management Task Force's (DMTF) Common Information Model (CIM) that provides a common definition of management information for systems, networks, applications and services, enabling vendors to exchange management information between systems throughout the network ([WebCim]).

While SID was initially telecom oriented, CIM was IP centric. However, due to the network convergence the models have become quite close to each other and there is also some overlapping. Therefore, DMTF and TMF established an alliance ([TMF/DMTF07]) that concentrates on the harmonisation of these models. The goal is to finish the harmonisation before November 2007, and for the industry the outcome should naturally be very beneficial: vendors and service providers of both organisations sharing a single, consistent model of technology through business perspectives. Both SID ([Sid07]) and CIM ([Cim07]) contain definitions of technological entities, such as physical and logical (MPLS, Ethernet, VLAN etc.) network resources, but SID describes the business entities, such as services, product bundles, SLAs and roles, as well. Although SID and CIM also describe logical resources, they are not actually used as an interface between management systems and network devices. Instead, they are used for modelling the resources in vendor independent manner, and the interfaces are then built separately. [Rfc3535]

3.5 Summary

This chapter introduced the general architecture of service providers' operational environment. TMF's eTOM model can be utilised when the roles of various OSS systems are defined. TMF's SID and DMTF's CIM frameworks provide tools for mapping the services with network layer, but in the most cases they offer only the guidelines, i.e. they cannot be seen as standards. Therefore the mapping between sold services and network level functions remains difficult to define, which also makes the service fulfilment process cumbersome. The process becomes especially complex when there is a need for network provisioning, i.e. network resources should be reserved for subscriber based on the availability and subscriber's location.

Automated service fulfilment process also needs extensive network element interface library and there are currently no commonly accepted management standards. Therefore it is vital that new interfaces can be attached as plug-in modules to service fulfilment solution and only transaction-driven processes are automated. The complexity of management languages means that it is better to execute rarely occurring management operations through command line interface (CLI).

Based on the research it can be summarised that lack of standards, commonly accepted OSS architectures, and the variety of services, technologies and network element interfaces complicates the implementation of commercial off-the-shelf service fulfilment OSS significantly, but also creates a great demand for such systems. However, due to these challenges the solution scope must be carefully considered.

4 Reference Service Fulfilment OSS Suite

The following chapter introduces a reference software suite that can be used when defining a NGN service fulfilment solution. Available software modules are described first, and then the general architecture for the NGN service fulfilment solution is presented. In terms of the eTOM process model (Chapter 3.2), the reference product portfolio positioning is apparent. The service fulfilment solution combines resource level capabilities of Inventory product with activation capabilities of Activation product and service management features of Service Management product, resulting in solution that is able to handle the whole service fulfilment process, and not only service activation.

4.1 Service Activation and Provisioning

All subscribers and services that are defined in the Operations and Business Support Systems (OSS/BSS), such as Customer Relationship Management (CRM) or order management system, have to be configured in the appropriate network element before customers can use their services. This configuration procedure is referred to as service activation or provisioning, depending on the usage Activation product forms a single service activation platform on which user and service information can be activated across different network technologies and Operations and Business Support Systems (OSS/BSS). Figure 12 illustrates the service activation on a general level.

Activation product is a service activation system through which a service provider can create subscribers, modify and query subscriber data, activate new services to existing subscribers, and delete subscribers and their services. Activation product automates the activating and provisioning of services in fixed, mobile, satellite, IP and data networks, so that no manual intervention is needed from the service provider's personnel. OSS/BSS systems do not need to have profound knowledge of the network itself; Activation product takes care of the communication with network elements. Activation product architecture contains several layers and components. The main architecture includes OSS/BSS Interfaces, Request Engine handling the request execution, Task Engine taking care of the task sending to network elements, Network Element Interfaces, Network Model Manager and database where everything is stored.

Activation product can receive activation orders from any OSS/BSS, and can be used in a variety of different network domains. Activation product has interfaces with various

OSS/BSS systems and network element types. Typical network elements in a mobile operator include Home Location Register (HLR), Authentication Centre (AUC) or Lightweight Directory Access Protocol (LDAP). For a broadband operator, Activation product may process requests into network inventory, element management systems and value-added service elements such as e-mail, VoIP, and IPTV. Figure 13 illustrates the position of the Activation product in the operator's network.

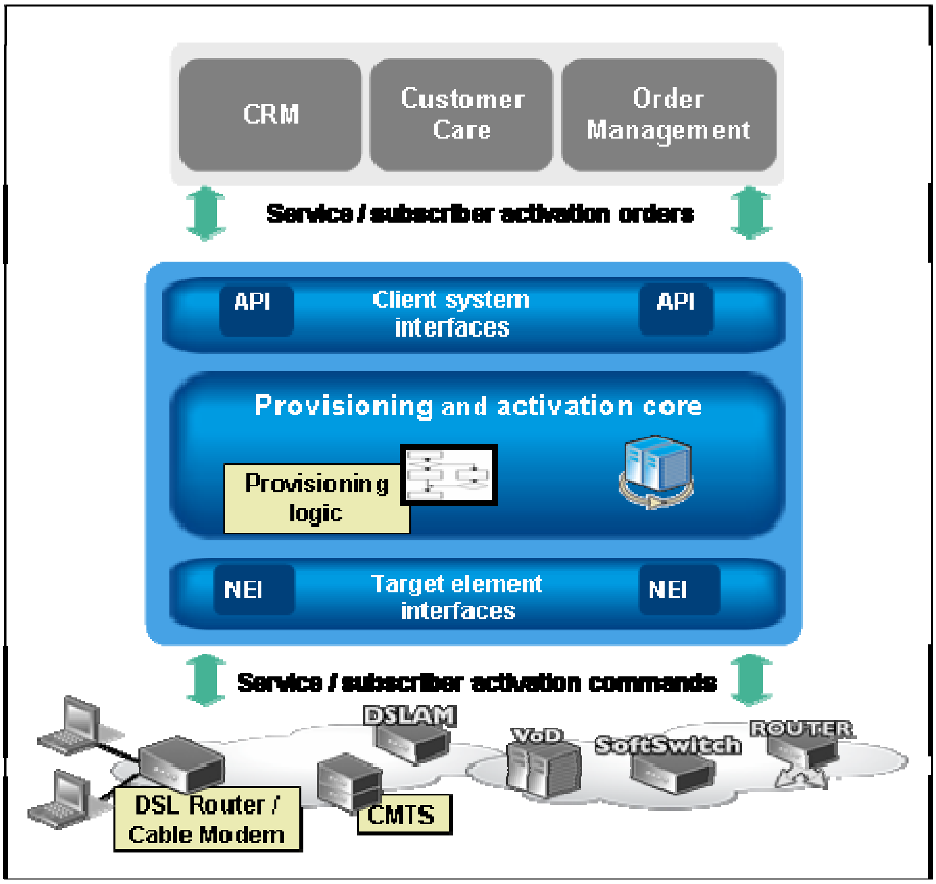

Figure 13 Activation Product - General Architecture

An OSS/BSS sends service requests to and receives responses from Activation product through OSS/BSS (northbound) interfaces. Activation product activates services using configurable processing rules into a network that has a number of different types of interfaces. Processing rules are configured using Provisioning Logic Configuration Tool. Provisioning logic processes requests from OSS/BSS systems, generates the tasks to be sent for network elements through network element (southbound) interfaces and creates a request response that is sent back to OSS/BSS system.

Provisioning Logic Configuration Tool allows service providers to create and modify their provisioning logics through a web-based user interface. The provisioning logic is a set of rules that define how provisioning is performed, enabling complex request processing. The provisioning logic is first constructed using the Provisioning Logic Configuration Tool user interface and then activated to the Activation system. In this way, the entire request-handling logic can be easily controlled. Figure 14 shows simplified picture of provisioning logic.

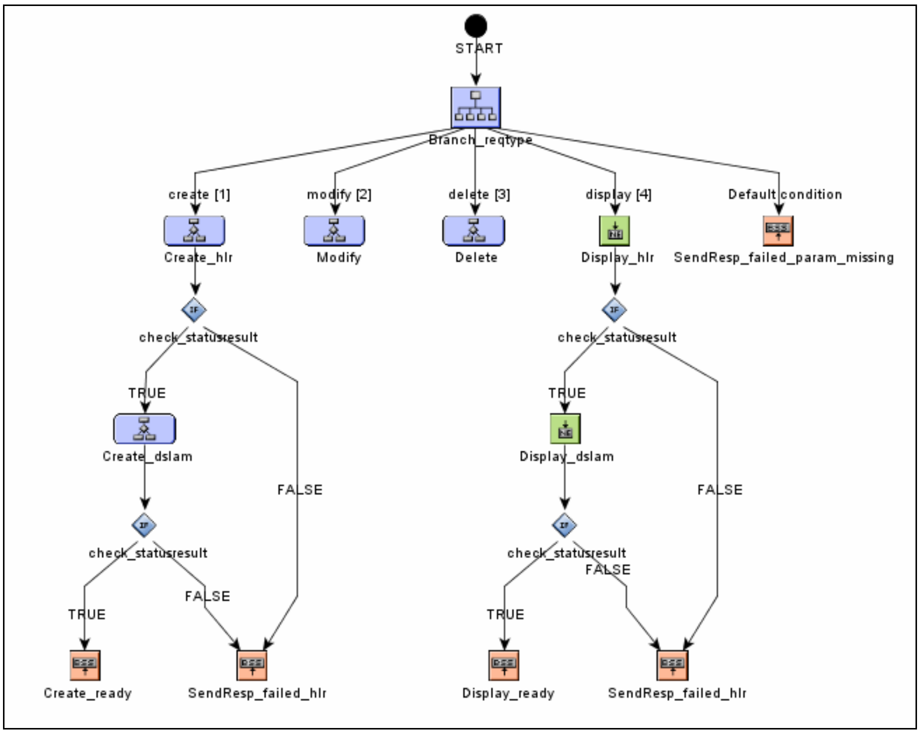

Figure 14 Provisioning Logic in Provisioning Logic Configuration Tool

Activation product sends the commands generated from the service requests to the network elements across the network element interface (NEI). The network elements also send response data to Activation product across this interface. Activation product can support several network element types and versions simultaneously, and new NEIs can be easily added to the system as plug-in modules.

NGN Challenges

Activation product cannot perform network provisioning functions without a network inventory. Traditionally service activation platforms have stored only the connection details between the activation platform and network element, but in NGN service fulfilment for example network hierarchy or network element locations must be known. Also, although the Provisioning Logic Configuration Tool allows service providers to flexibly manage their service activation and network provisioning workflow, it does not offer service management functionality. Service management enables service providers to rapidly develop new service bundles, and managing services becomes easier since all service information is centralised to one location.

4.2 Network Resource Management

Inventory product is a network inventory solution that allows fixed, mobile and cable service providers to manage their network assets. Inventory product is developed in close collaboration with several Tier 2 operators and brings together, in a unified solution, all the information and functionality that is traditionally distributed across multiple systems and sometimes paper-based documentation. Figure 15 illustrates Inventory product in the service provider's network.

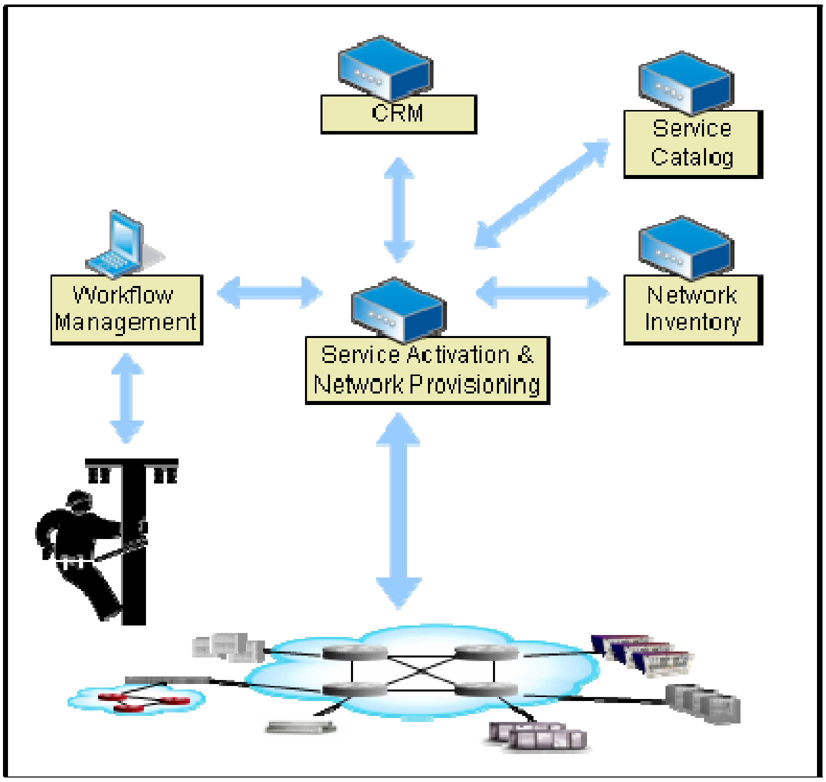

Figure 15 Network Inventory in Service Fulfilment

Inventory product utilises [ItuG.805] standard, and is designed to support existing and emerging access and transport network technologies. Supported access technologies include all types of Digital Subscriber Lines (xDSL), optical (FTTx) and cable (HFC) technologies. In transport, technologies such as Frame Relay (FR), Asynchronous Transfer Mode (ATM), Synchronous Digital Hierarchy / Synchronous Optical Network (SDH/SONET), Multiprotocol Label Switching (MPLS), Metro Ethernet and Internet Protocol (IP) can be modelled.

Inventory product is built on an extensible object model, in which extensions are held separate from the core, allowing upgradeability while maintaining customer-specific functionality. Inventory product is based around three core inventory modules (see Figure 16): logical resources (connectivity), physical inside plant and physical outside plant. Logical network can be modelled by taking into account factors such as physical constraints (resistance, attenuation), capacity (bandwidth, equipment) and business rules. Inside plant inventory contains multi-vendor equipments, such as Customer Premise Equipment (CPE), switches, routers, multiplexers, 2G and 3G equipment for mobile. The details recorded include the connectivity between pieces of equipment, their capacity (for example, free ports) and the equipment locations (for example, shelf, frame, rack, row, room and site). Outside plant module supports the full inventory of the underground and aerial physical resources of the network, such as ducts, pipes, cables, splices, distribution boxes and radio links. Outside plant module also includes an integrated Geographic Information System (GIS) capability, which allows resources to be positioned on maps. Migration module allows population of inventory data from legacy systems, while the reconciliation module provides a capability to load information into Inventory product, and reconcile that information with information already held in the inventory. This information can be also used for monitoring purposes. IP Address Management is an additional software module that can be used for managing and storing the service provider's IP addresses. Figure 16 illustrates these different Inventory product modules.

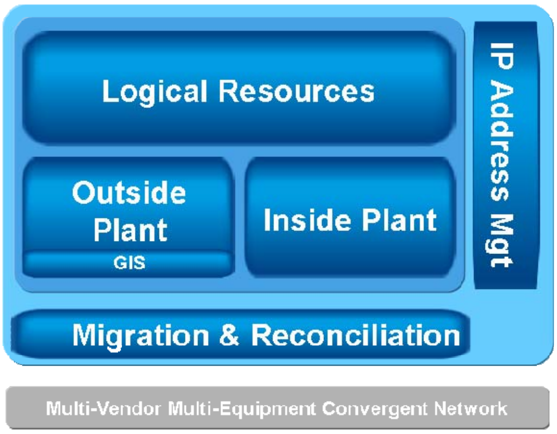

Figure 16 Inventory Product Modules

Inventory product modules are fully integrated, providing a solution that is able to support the network media, protocols, equipment and logical connectivity of access and transport networks used by broadband, mobile and cable operators. This allows a progressive deployment of Inventory product, for example, starting with one particular module and then expanding to the others.

Inventory product enables the modelling of networks at the following levels: track network that describes the geographical location of the telecommunication equipment, duct network that describes the physical equipment in which the cables are located, physical network that defines the physical cable level and logical resources that defines the connectivity and assignment in both the access and transport networks. The logical network is modelled using the concepts based on [ItuG.805]. Inventory information includes everything inside the plant down to port level and transmission technologies. Although the standard was originally designed to model transport networks, it is also being used in Inventory product to model access networks, providing a consistent vendor and network independent end-to-end view. The standard's components are independent of implementation technology, and can be applied to any network. They process information between inputs and outputs, and are associated together to form the network elements and then networks. Figure 17 illustrates how different network layers can be modelled to Inventory product.

Very important concept for NGN services is tunnelling, which is used to transport a network protocol through a network. Tunnel layers can be created and named by system owner (e.g. LSP, VLAN etc.) and they can be configured to support any technology. In Inventory product a tunnel is connectivity layer offering capacity to carry another layer, and can be modelled as a standard technology package. Figure 17 shows how IP services can be modelled to run on the top of VLAN which at the same is built on top of Ethernet.

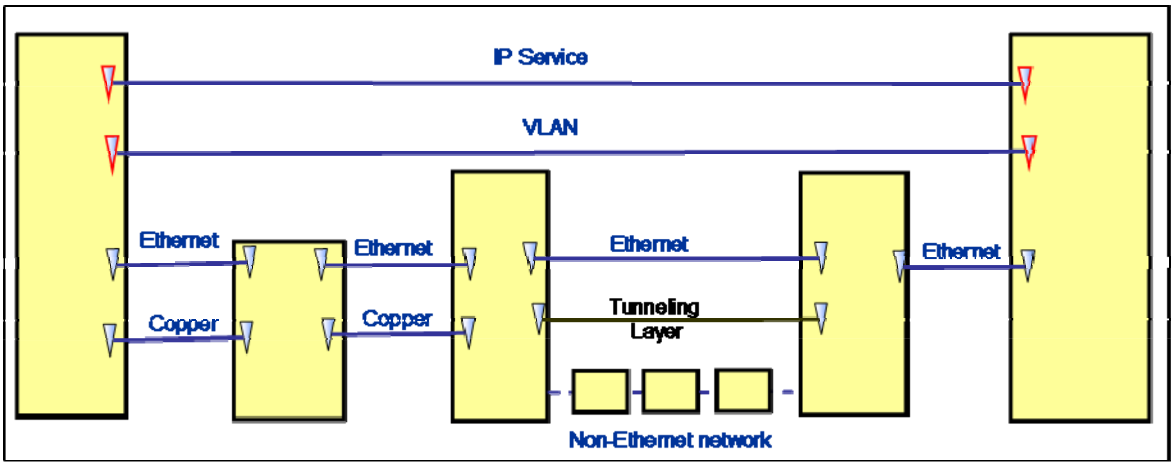

Figure 17 Modelling Layers in Inventory Product

Another important concept is the network “cloud”. Inventory product can model VPNs and other “cloud” objects by using a “sub-network”. When a part of the network is “hidden” from the layers above, a sub-network is used, to show entry and exit points (e.g. ports) to the "cloud". For example in VPN, the VPN access is connected to a Provider Edge router, and to the cloud. How the traffic gets from the ingress PE to the egress PE is irrelevant for the VPN, and is hidden by the cloud (Figure 18).

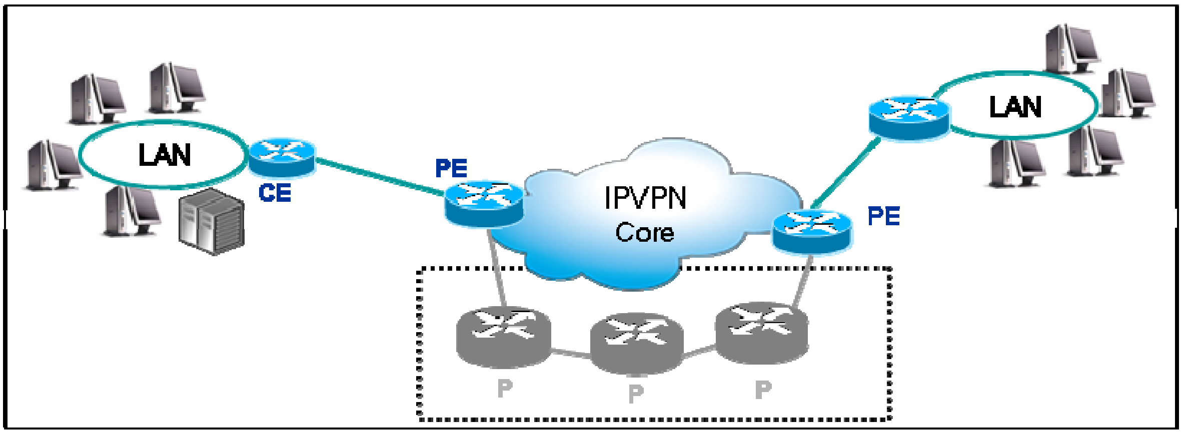

Figure 18 Network Cloud in Inventory Product

NGN Challenges

New technologies are emerging all the time, which makes the network modelling very complex. Therefore it is important to follow the work of standardisation bodies discussed in this study. Network inventories should also be very flexible and configurable, but at the same time easy to use. Therefore, the network inventory should support different levels of stored information. If the service provider is not willing to use the system for general network management and record all their network data into it, but only the information required in service fulfilment process, the network inventory should hide the unused features and show the essential information in an easily achievable format. Modular design is a key for this.

4.3 Service Management

The ability to develop and deliver innovative services fast, reliably and cost-effectively is now the key strength for service providers. Traditionally each system has been holding information on services inside the system, and this has resulted in very scattered service data (see Figure 19). This makes the service provider's environment very inflexible and increases the time to introduce new services or configure existing ones. With Service Management product, service providers are able to centralise all product and service data into a single system (see Figure 19) and thereby enable rapid introduction of new services.

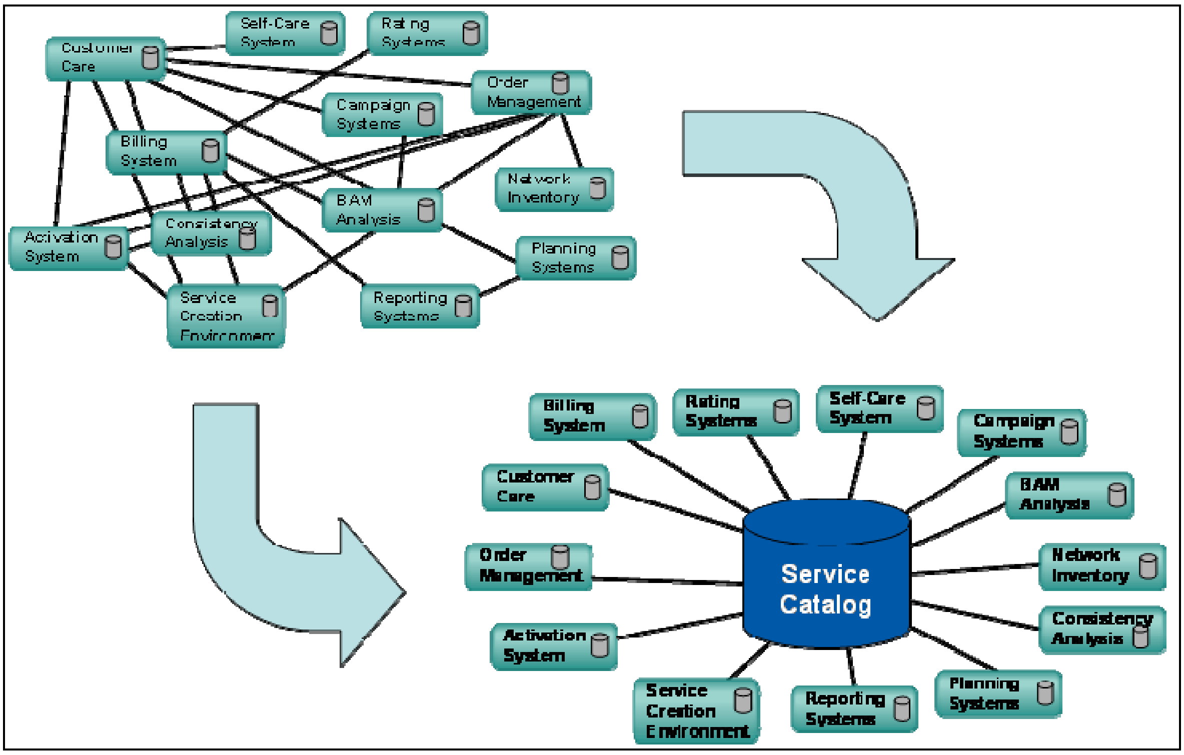

Figure 19 Service Management Product - Centralising the Service Information

However, mapping products and services, as marketed to their customers, with their actual implementation in the network can be relatively complex. For example, provisioning and activating a particular service, or calculating the service charge, may require multiple and often complex actions at a network level. In order to make this process easier, service catalogue enables fast and easy configuration of the technical services into sellable services and products. In service catalogue, service provider's offerings are divided into three layers: products, services and technical services (see Figure 20), which naturally support versioning and service provider's live cycle states. Products change very often and are driven by the business, i.e. what is sold to customers (e.g. Triple Play package). Services are the service provider's internal presentation on services (e.g. DSL or VoIP subscription), which are sold to customers through products. Services also change quite often, for example when the service provider wants to introduce new variations of the same service. Technical services are driven by the network, i.e. what services are supported by the network layer (e.g. 4 Mbps broadband connectivity using ADSL combined with some QoS parameters). Technical services change very seldom and they must be defined only when new network equipments are introduced.

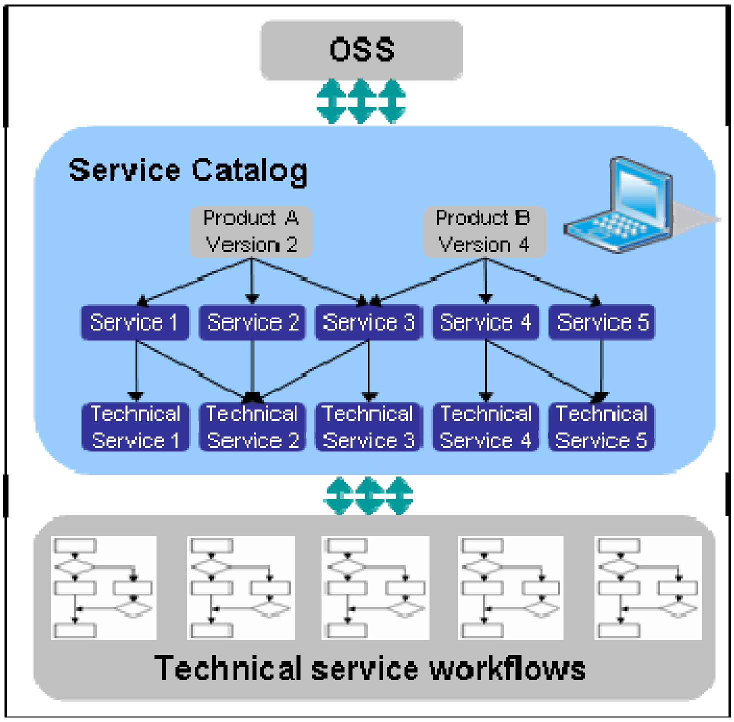

Figure 20 Mapping Products to Technical Services

The technical services returned by service catalogues are decomposed to technical service workflows (provisioning operations) by the provisioning logic. Provisioning logic can use the capability library in solving the operations out from the technical services. Capability library stores the information about network element capabilities and interfaces. The decomposition of a technical service to provisioning operations may be different between two capability library instances (e.g. depending on the network element vendor), but this is hidden from the service catalogue user.

NGN Challenges

Mapping the service to technical service will be challenging. However, as discussed in Chapter 3.4, the industry is currently studying this area, and the outcomes should naturally be utilised. The Service Management product must also be very flexible and extendable, because it needs to hold service information that can be used not only by the service fulfilment system, but billing and other systems as well.

4.4 Other Modules

The three mentioned software modules constitute most of the NGN Service Fulfilment solution, but there are also other modules that could be considered to be used. Mediation product, which is traditionally used for collecting billing and statistical information from network elements, could be used for collecting data (usage rates, alarms etc.) from the network and mediate this information to Inventory product. However, this requires additional research, and is left for future studies.

Second optional software module is Workflow Management product that provides support for manual activities in activation work-flow process. If activation workflow must be interrupted, e.g. manual device installation is required before activation can be finished, the activation engine can send a ticket to Workflow Management product. Using Workflow Management product's web-based UI, a field engineer can install the device according to instructions found from the ticket, and eventually send the ticket back to the activation engine where the activation workflow then continues.

4.5 Overall Architecture

The presented, the principle building blocks for the Service Fulfilment Solution are:

- Inventory product, providing the resource management component,
- Activation product and Provisioning Logic Configuration Tool, providing the activation work-flow, activation interfaces and the mechanism for integration to Inventory product, and
- Service Management product, a component promoting the modular design of products and enabling agility in the architecture. The service fulfilment solution can be delivered without the Service Management product, but the market is generally accepting that a service catalogue is an integral part of a best-of-class type solution. Without the service catalogue, solutions are more hard-coded - unable and vulnerable to change.

Figure 21 describes the general architecture and workflow for the presented service fulfilment solution.

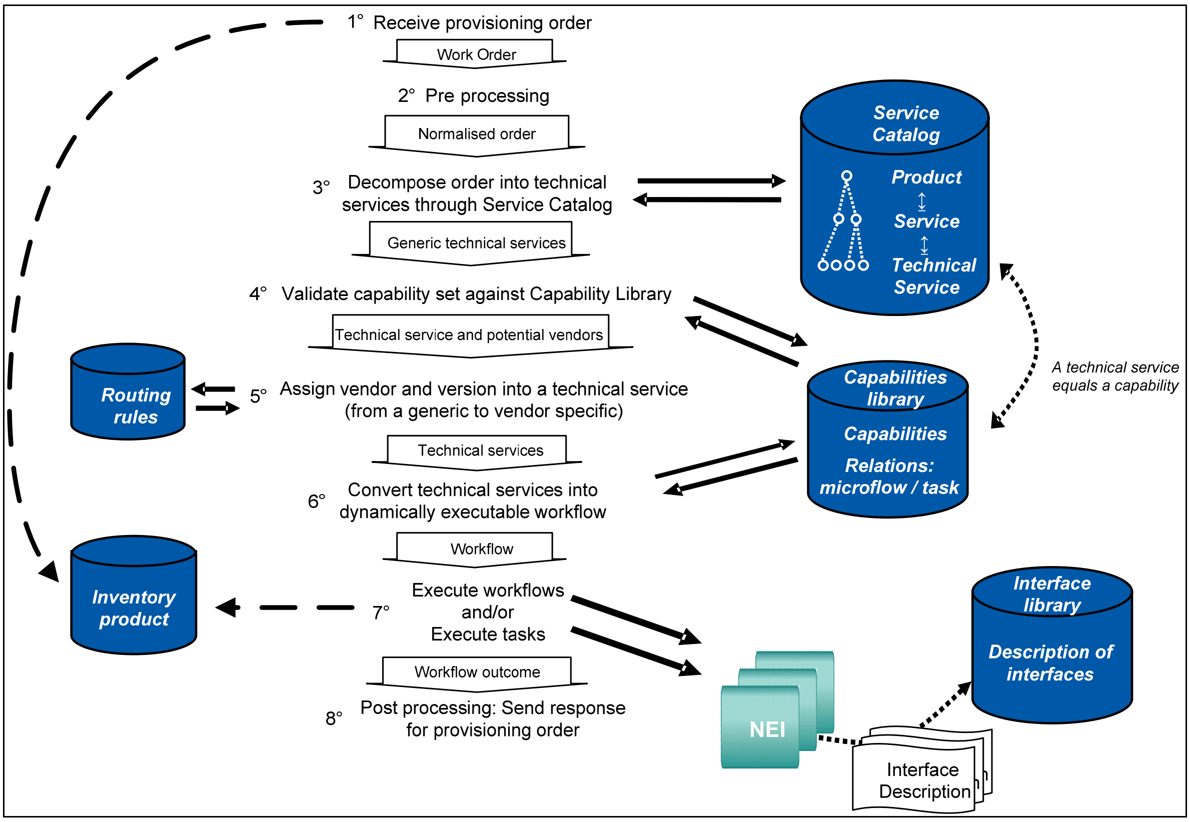

Figure 21 Service Fulfilment Solution Workflow

The steps in the Figure 21 are as follows:

1st, Activation product receives the provisioning request from the OSS/BSS system. The order is stored into a database and execution is started.

2nd, the correct workflow is selected (e.g. activate residential broadband) and Provisioning Logic Configuration Tool starts executing the workflow (provisioning logic). At this stage it is possible to do for example additional validation for the request parameters or make some modification to the data in order to convert it into a format that is valid to be sent into the Service Management Product for product decomposition. If there is need to do for example pre-qualification based on referred service for customer location through Inventory product, it can be executed in the pre-processing phase.

3rd, the request data, regarding referred product instances for a subscriber, is sent into The Service Management product for processing. The Service Management product makes the decomposition from referred single or multiple products down to a set of technical services. The service inventory can be referred to in order to gain an understanding of the customer's current product and service set.

Service Management product then sends back only the set of technical services with possible assigned parameters. Each technical service reflects to single capability of the service provider's network. Capability on the other hand can refer to atomic tasks or composites build from workflows.

4th, in case there are some capabilities that are only supported by some network elements in the service provider's environment, information stored into the capability library can be used for checking if the set of technical services can be supported by service provider's network. Another scenario is that only one of the two elements supports all requested technical services. This has to be identified and informed to the routing process, since the only option is to assign referred technical services to the element that is capable of supporting them. This issue is raised only in a multi-vendor environment by limitations of capabilities of some network elements.

5th, before it's possible to construct the commands needed on the network layer for desired operations, vendors and versions to each technical service must be assigned in order to identify the executables. This can be done through the routing rules, which contain rules for each technical service type (network element type), i.e. how to assign a vendor and version for it, and eventually assign the correct micro-flow. After this process the micro-flow for each technical service has been identified.

6th, when the technical services are assigned with vendor and version, it's possible to construct the executable workflow using the capability library.

7th, the execution tree is then executed through the Provisioning Logic Configuration Tool. Each capability is executed into the network and execution status is assigned for a technical service. The execution engine executes each defined task, dynamically calls executed micro-flows and manages parameters. The micro-flows can interface with network inventory in order to reserve and commit resources.

8th, the logic is able to react to each technical service status by rolling back, continuing or stopping the workflow. The post-processing can be used to make some customer-specific alterations, modifications into the data or just simply to construct the response for the OSS/BSS system.

4.6 Technical Key Challenges

There are few challenges that must be overcome when service fulfilment offering is defined. Although challenges related to actual technical implementation exist, the focus is on the challenges above the modular level.

Modularity and Interfaces

First, data must not be replicated into several systems. Network inventory contains resource information, service catalogue service information, and the activation system is only a flow-through provisioning system interfacing all network elements and managing the whole workflow. This requires clear definitions of modules, in which TMF's eTOM and SID, and DMTF's CIM frameworks should be utilised.

Modular design causes challenges with interfaces because resource information and activation are closely tied together, but reside in separate modules. Interface between activation platform and network inventory must be very feature-rich and clearly defined, otherwise the provisioning process gets too complicated. Sending a single task should be preferred to sending several incremental tasks. For example, when an ADSL trail is reserved, it must be enough to send one task to the network inventory (requesting DSLAM information), instead of several incremental ones. This way all the resource specific intelligence can be maintained in network inventory and the activation platform does not need to know how the resources are actually managed.

It must be considered how to handle situations where service (ADSL, VPN) must be re-routed due to the changed network environment. The basic idea of the system is that Activation product manages the provisioning process and requests resource information from Inventory product when necessary, but for this kind of re-routing the initiating system would probably be Inventory product. This means that a northbound interface between Inventory and Activation product must be defined or the Inventory product architecture must be slightly modified. It does not make sense to implement a network facing configuration capabilities both to Inventory and Activation product.

Application Scope

The traditional differences between network inventory and service activation systems are problematic. Service activation systems have aimed at highest possible level of automation, while the network inventory systems have been quite static systems, containing all information from physical to logical network level. However, it is not feasible to include all information on physical resources to system that is only doing network provisioning. The network inventory should be configurable enough to adjust to scenarios where different levels of physical and logical information are stored. Users should only see the information they require.

There must be a clear insight whether the overall system should be used only for network provisioning or also for network management. While the network provisioning includes only the processes that occur often and are closely related to specific customers, network management happens rarely, mainly during network setup and maintenance. Expertise in service activation is better suited for automating the service fulfilment process, and not to prioritise the network management function. Also, due to the system architecture, where the Activation product is acting as provisioning engine and facing the network elements while the resource information is stored in Inventory product, it is not feasible to use the system for large-scale network management operations. This would require implementing a northbound interface between Inventory and Activation product, and several southbound interfaces between Activation product and network elements. And as discussed in Chapter 3.3.2, the interface implementations can be very complex, meaning that unless the network operations are commonly needed, implementing the interface does not justify the effort. Modelling the whole network to Inventory product would also be very cumbersome, due to the large number of legacy and emerging technologies.

5 Service Fulfilment OSS Market Analysis

Porter's Five Competitive Forces framework ([Por79 and [Por80]) is used for analysing the service fulfilment Operation Support Systems (OSS) markets. We evaluate how attractive the markets are and consider different obstacles that must be overcome in order to be profitable. According to Porter's model, the five forces (Figure 22) that affect on the industry are threat of new entrants, intensity of rivalry among existing competitors, pressure from substitute products, and bargaining power of buyers and suppliers. After analysing these five factors the industry pros and cons will be summarised, and the next chapter then evaluates feasible solution scenarios for a OSS vendor.

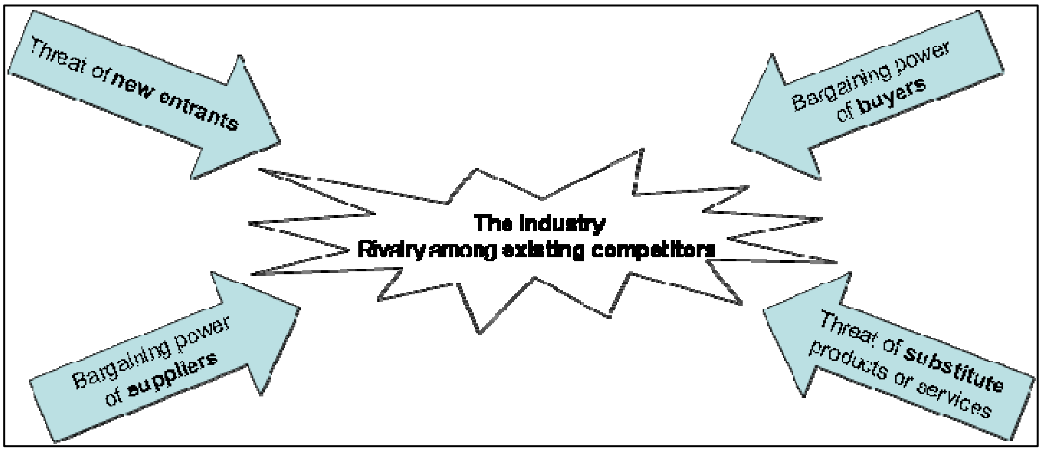

Figure 22 Porter's Five Competitive Forces Framework

5.1 Threat of New Entrants

Barriers to entry protect the existing industry players from new entrants. In this chapter we evaluate these entry barriers according to Porter's framework.

Economics of scale

The economics of scale naturally affects, because the development costs of Commercial Off-The-Shelf (COTS) service fulfilment OSS can be distributed when there are several customers. Although network environments are largely diverse between the service providers and there is always need for customisations, developing a viable core product consumes lots of resources.

Product differentiation

Product differentiation is important, because service providers or system integrators are unwilling to operate with an OSS vendor that does not possess the technology domain specific experience and whose software does not align to domain specific requirements. Service fulfilment in NGN (broadband and IP) networks requires a different kind of expertise than traditional service activation (see Chapter 3.3). Therefore, it is vital to gain the expertise and communicate new capabilities to potential customers as well.

Capital requirements

Capital requirements are relatively significant, because developing and maintaining the software capable of complex fulfilment scenarios is expensive. Customisations and emerging technologies cause high demands for software's flexibility and upgradeability. Building interfaces to new network elements does not pose a significant cost, but network inventory related functionality is more difficult to manage. While the interfaces can be quite simply implemented as plug-in modules for the core software, support for new technologies is more complex to implement in network inventory, in which tecnologies are closely dependant on each other.

Switching costs

The switching cost for the service fulfilment system can be very high. It prevents acquired customers from switching to another OSS provider, but also discourages service providers to replace their existing, often not very efficient, legacy systems.

Access to distribution channels

System integrators usually manage the delivery of service provider's new network environment, including service fulfilment OSS, and therefore they are in a vital role when OSS vendors are selected for new projects. Good reputation among system integrators and successfully delivered projects are very valuable, because the preferred partners are naturally awarded with new projects. For newcomers this is clearly a challenge, because without proper references they are unable to win projects. Newcomers should either target smaller service providers directly or utilise their existing reputation from a slightly different sector, such as from mobile service activation.

Cost disadvantages independent of scale

None of the service fulfilment OSS providers are substantially large, but they still are in favoured position compared to entrants. As stated before, they have the experience from working with system integrators, and they also have valuable knowledge of the different service fulfilment processes, i.e. they know what kind of issues should be considered.

Service fulfilment in NGN networks can be very complex process, as discussed in Chapter 3.3, and therefore service providers are not necessarily capable at identifying all their requirements. Instead, they expect OSS vendor to have this expertise.

Government policy

Government policy does not play a very large role, because in most countries telecommunications have already been deregulated and markets opened for competition. The biggest boom for establishing new service providers has also passed already, which means that the demand for completely new OSS setups has decreased.

5.2 Existing NGN Service Fulfilment OSS Vendors

Intensity of rivalry among existing competitors affects greatly on the market attractiveness. First, we analyse the existing competition situation according to criteria suggested by Porter, then we introduce the main OSS vendors and evaluate their positions in the market.

Numerous or equally balanced competitors

There are no clear dominant players in the service fulfilment OSS sector, as figures in Chapters 3.3.6 and 5.2.1 show. Although this indicates there would be space for new entrants, as Porter reminds, this also creates instability, because no dominant player is imposing discipline. Equally balanced competitors are prone to fight each other. For example the current standardisation situation (discussed in Chapter 3.1) highlights the fragmented industry structure.

Slow industry growth

The industry is still growing, as stated in Chapter 3.3.6. However, most of the selling is targeted for established service providers that already have existing service fulfilment and network management environments. This, coupled with many equally balanced competitors seeking expansion, makes the market very competitive and complicates market entry.

High fixed or storage costs

Fixed costs are relatively high, because software must be continuously developed to support new technologies. Research and development expenses for first-class COTS service fulfilment solution can be significant and therefore OSS vendor might be willing sell new projects for compensated price in order to receive long-term income from support. Setting up and maintaining a service fulfilment OSS is an extensive task and generates work and profits years ahead. For new entrants this is naturally problematic, because they do not have a large customer base that could compensate for their high development expenses.

Lack of differentiation or switching costs

The impact of differentiation and switching costs were discussed in the previous chapter and it was concluded that both of them protect established, reputable OSS vendors from competition.

Capacity augmented in large increments

Research and development efforts for service fulfilment COTS software can be loosely estimated beforehand, but delivery projects require more forethought. Since the delivery projects are usually very large, long-lasting and require domain specific knowledge, the personnel resources must be considered carefully. Hiring new personnel is expensive and leads into overcapacity when there are less new projects. Therefore, it must be evaluated whether the OSS vendor should be purely a software house offering licenses or also offer delivery services. Partnering with system integrators and allowing them to tailor the software for the service provider's needs, would decrease the risk of overcapacity and allow more simultaneous delivery projects. This would naturally decrease the profits from services and generate new requirements e.g. for more advanced training, but could be a good approach for new entrants who need to establish good relations with system integrators.

Diverse competitors

OSS vendors have different strategic approaches towards solution scope. While some vendors are very product centric, some promote solution specific approach (see Chapter 5.2.1 for further analysis). The backgrounds of vendors also vary significantly – while service fulfilment is the core business for others, for many it is only one mediation business among others. This increases diversity and leads to vendors running head first into each others, making it more difficult to agree on a set of rules of the game.

High strategic stakes

US based OSS vendors have been dominating North American markets, while European OSS vendors have been strong in Europe and nearby areas. Recently, OSS vendors have been trying to expand their operations, also through mergers and acquisitions, increasing the rivalry in different continents. There are no dominant OSS vendors in service fulfilment sector yet, and since each vendor is focusing on growth they might be willing to sacrifice some profitability.

High exit barriers

Service fulfilment OSS software contains extensive functionality, which is expensive to implement. Once the functioning COTS product has been built it is not easy to relinquish, although the vendor would not meet the target profitability level. Existing service agreements also force OSS vendor to give support, making it impossible to cease operations without considering contractual issues.

5.2.1 Market Analysis

Industry trend information (see Chapter 3.3.6 for market forecast) point to network provisioning being a growing market, which an OSS vendor can use to its advantage with a suitable product set. Service providers are beginning to demand convergent solutions which incorporate activation, work-flow, inventory and catalogues. However, competition is tightening as there are lot of small players coming to market. Figure 23 estimates current positions in the service fulfilment markets.

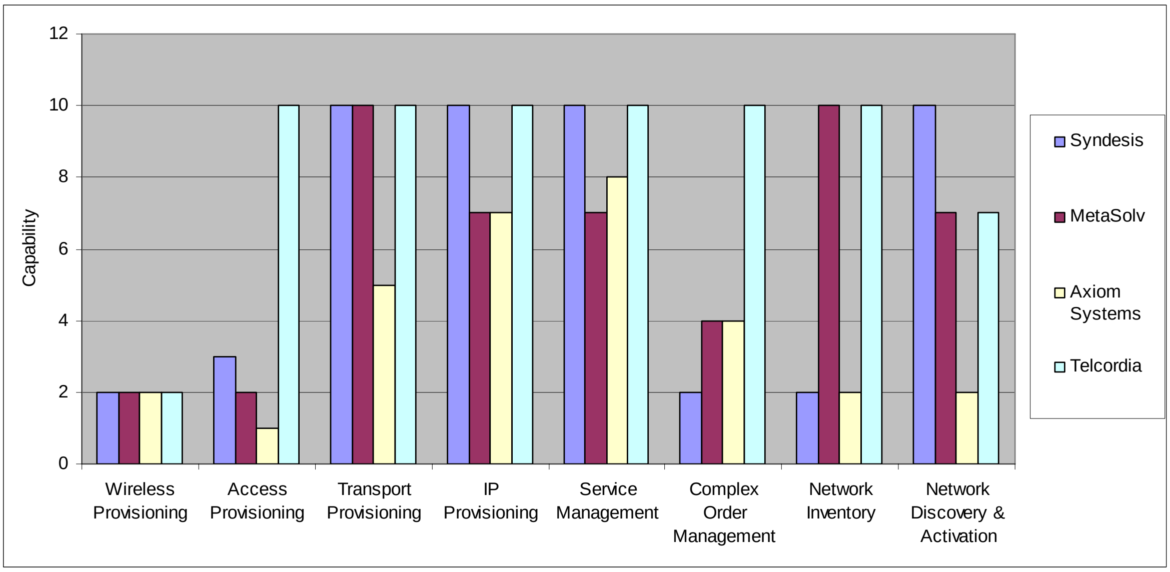

Figure 23 Service Fulfilment OSS Vendor Capabilities [Dit06]

The capabilities (0-10) are presented according to [Dit06] and they highlight how service activation (wireless provisioning) is different from network provisioning (transport and IP) and service management. [Dit06] also evaluates several other OSS vendors, but only the strongest players in network provisioning are presented in Figure 23. For example Amdocs and Netcracker have significant market shares in network inventory management, but since they are lacking of competitive network provisioning and service activation solution, they are not taken into consideration in service fulfilment category. Although the capabilities are only suggestive, and markets are changing rapidly with new product releases, the selected OSS vendors are on markets and therefore their solution sets are analysed. The focus will be on broadband and IP services service fulfilment, solutions for mobile will not be covered.

Telcordia

According to [Gol07] Telcordia is the most experienced and largest OSS vendor in very fragmented OSS markets. Telcordia's market share in service fulfilment is 13%, and while it sounds relatively small, Telcordia actually captures a market share that is more than twice as big as the second rival's. However, a significant portion of Telcordia's market share comes from US legacy markets where they provide professional services to their large, existing customers (e.g. AT&T, BellSouth and Qwest), and less is actually product based revenue. Telcordia's service fulfilment product suite is very extensive and consists of several different modules: network provisioning and service activation, discovery, network inventory, service catalogue, order management, number management, workflow management and network engineering. Telcordia also offers service management product suite, and several other smaller products that are not listed here. However, because some of the Telcordia's products are obtained through acquisitions and partnering, there are some overlapping functionality, and Telcordia's offering appears to be more like a product toolbox than finished solution. Telcordia supports several tecnologies, such as SONET, SDH, DWDM, FTTx, PON, ATM, Frame Relay, DSL, IP, Ethernet and MPLS, and several IP services as well: IP-VPN, QoS, Traffic Engineering, VoIP and IPTV. [WebTel]

MetaSolv

MetaSolv (recently acquired by Oracle Corporation [WebOra]) offers products for order management, network provisioning and service activation, inventory management, network mediation and configuration management. MetaSolv promotes technology modules (e.g. for MPLS) that can be integrated together to form a complete service fulfilment platform. MetaSolv supports a long list of technologies, including ATM, Frame Relay, SONET, SDH, Optical, DSL, MPLS, Ethernet, and NGN services (e.g. VoIP and various VPNs). It is also capable of building a complete service fulfilment solution (including also the order management), and therefore should be seen as a strong player. [WebMet]

Syndesis

Syndesis (recently acquired by Subex Azure [WebSub]) is an OSS vendor that provides service fulfilment solutions purely on NGN (as defined in this study) networks. Syndesis has a solution based approach in serving their customers. It offers service fulfilment solutions for DSL, Ethernet and transport, IPTV, IP-VPN, Triple Play and VoIP, and utilises its large product library in these solutions. Syndesis' solutions are combined from several different modules: order management, network inventory and discovery, service catalogue, network provisioning and service activation, and network optimisation. Syndesis also highlights the possibility of combining several of their solutions together: for example the transport solution can be used to deliver only connectivity services (e.g., ATM), or it can be integrated with VoIP, IP-VPN and Triple Play solutions to provide end-to-end service fulfilment. [WebSyn] This allows service providers to concentrate first on a tactical solution, but ultimately extend to strategic solutions. For Syndesis, this naturally means that they are able to generate more revenue from their existing customers in the long run. Although Syndesis is a small company with only 300 employees ([Dit06]), its customer base contains even Tier 1 service providers.

Axiom Systems

Axiom Systems concentrates mostly, alike Syndesis, on service fulfilment in IP networks, leaving the mobile space for more established competitors. Axiom Systems' product suite consists of order management, network inventory, service catalogue, service activation, network provisioning and integrated IP and number management modules. Axiom Systems promotes mainly solutions for different use cases: DSL, IPTV, IP-VPN, Metro Ethernet, Triple Play, IMS and Mobile, but also tries to make its AXIOSS product suite more known. According to [WebAxi], Axiom Systems devotes to the latest technologies, e.g. IP-VPN solutions supports for example ATM, Frame Relay, Ethernet and MPLS.

Summary of NGN Service Fulfilment OSS Vendors

Table 1 lists the network technologies and services that the previously presented OSS vendors are supporting according to their web sites. Table 1 also shows the different service fulfilment modules the selected OSS vendors are promoting, and whether they pursue a product (*strategic*) or solution (*tactical*) based approach.

Table 1 Summary of Offered Service Fulfilment Solutions from Different OSS Vendors

	Products or solutions	Offered solutions	Technologies
Telcordia	Products	-	ATM, DWDM, DSL, Ethernet, Frame Relay, FTTx, IP, MPLS, PON, SONET, SDH, IPTV, IP-VPN, QoS, VoIP
MetaSolv	Both (solutions as technology modules)	IP services, Cable and broadband services, Ethernet, ATM Frame Relay, MPLS, DSL, SONET/SDH	ATM, Cable, DWDM, Ethernet, Frame Relay, IP, MPLS, Optical, SDH, SONET, VLAN, VPLS, xDSL
Syndesis	Solutions	DSL, Ethernet and Transport, IPTV, IP-VPN, Triple Play, VoIP	ATM, Ethernet, Frame Relay, FTTx, IP, IPTV, IP-VPN, MPLS, SDH, SONET, xDSL
Axiom Systems	Mainly solutions	DSL, IPTV, IP-VPN, Metro Ethernet, Triple Play	ATM, xDSL, Frame Relay, Metro Ethernet, MPLS

As Table 1 presents, the more established and experienced OSS vendors (Telcordia and MetaSolv) are able to provide a versatile service fulfilment platform that is able to handle several different technologies. However, their solutions are usually quite heavy (especially Telcordia's), requiring lots of configuration, which can lead into expensive deployments. It should also be evaluated how well these systems are able to align to NGN technologies, because their background is in older technologies, such as ATM. Smaller OSS vendors, Syndesis and Axiom Systems, are focusing on tactical solutions, but can be lacking of functionality to grow into strategic solutions.

As the earlier research and the market analysis shows, NGN Service Fulfilment OSS vendor should focus on specific needs (DSL, VPN etc.), but also allow service providers to combine these different solutions into converged solution. This will be more beneficial on the long run.

5.3 Pressure from Substitute Products

There is ever-increasing need for telecommunications, and although lots of standardisation is occurring to harmonise the management modules and network element interfaces, there will be always a need for integrating the separate part of these systems and network elements together. As stated in earlier chapters, the network management complexity is only increasing along with new functionality. The number of competing network element vendors and requirement for supporting legacy technologies also ensure continuous demand for service fulfilment OSS systems.

Two potential substitute products for service fulfilment COTS OSS can be considered: in-house developed customised OSS software and network vendor specific management software. However, the first alternative is in the most cases considered as much more expensive solution (see Chapter 3.3.6) and the second option leads into siloed architecture. Management software that is provided by network vendor is usually bundled to equipment and therefore pre-integrated and less costly, but the problem arises when there is equipment from several vendors present. OSS is needed at least to integrate the vendor specific solution together.

5.4 Bargaining Power of Buyers

While the service providers and system integrators are globally significant players, OSS vendors are often relatively small companies, dependant on steady flow of new projects. Bargaining power of buyers is therefore an evident risk.

Large or concentrated buyers

The size of the buyer varies a lot: some of the sales are done directly with small service providers, some go through large system integrators. Especially system integrators and multinational service providers are strong buyers, because they might award several projects to the selected OSS vendor, and therefore expect significant price discounts.

Purchased products represent a significant fraction of buyer's costs

When service providers are upgrading or expanding their network or offered service spectrum, service fulfilment is only one, relatively small, piece of the whole process. However, the cost can be quite significant and therefore service providers judge the different options carefully. Service providers can not only evaluate the price of the new OSS solution, they must also consider migration costs, which occur from transferring the data from legacy systems to new system. This cost can be significant especially if a large amount of network inventory information is stored.

Standard or undifferentiated products

Available COTS service fulfilment OSS products vary greatly in terms of usability and flexibility, although the lists of supported technologies that service fulfilment vendors promote closely resemble each other. Customer references are very important, because service providers are not willing to make large investments before hearing real-life experiences about the product.

Low switching costs

As stated earlier, switching costs are rather high, which means that OSS vendors might be willing to sell their licenses at discounted price, but compensate this with higher service margins.

Low profit buyer

Deregulation of telecommunications multiplied the rivalry between service providers and forced them to cut unnecessary costs. As [Ban06] states, investments to OSS systems also decreased. However, nowadays OSS systems are seen as a device to increase automation and thereby reduce expensive manual work. Service providers are very price sensitive, though, and since majority of sales go through system integrators, who also want their part, there is a risk of low margins.

Buyers pose a creditable threat of backward integration

As stated in Chapter 3.3.6, COTS solutions are nowadays considered as better alternative than in-house developed software. However, most service providers still have their existing legacy OSS running and lots of expertise related to them. Therefore, the risk that COTS solutions would be replaced by either in-house or system integrator developed customised software cannot be ignored.

Product is unimportant to the quality of the buyer’s products or services

Service fulfilment is in an important role when customers evaluate the service provider’s service; although service providers do not necessary see it as a revenue generator similarly as they see e.g. billing related functions. Flexible and dynamic service fulfilment not only enables rapid generation of new services, but also e.g. allows customers to manage their services by themselves, decreasing the service provider’s customer service expenses.

Buyer has full information

Service providers or system integrators can easily request proposals from several OSS vendors and then evaluate the offered package based on price, functionality and other attributes. However, detailed estimation can be difficult to produce, because network environments and requirements can be quite different between service providers. Therefore the buyer values experience from similar projects. OSS vendors also allocate the license price versus service cost ratio differently, which increases buyer’s difficulty in estimating the actual price.

5.5 Bargaining Power of Suppliers

Generally, the bargaining power of suppliers does not have a great impact on OSS industry, because in software business most of the resources are internal, e.g. employees. Naturally software tools and other applications (such as Oracle database software) are purchased from external sources, but for these suppliers OSS industry is only one source of revenue and their prices are well-known. Advancing open source industry is also increasing the competition, which causes price pressures for these suppliers and makes the software development less expensive. Therefore, it can be estimated, that bargaining power of suppliers does not pose a threat when considering entering the service fulfilment OSS sector.

5.6 Summary

Porter's five competitive forces framework was used to analyse what kind of obstacles there are for an OSS vendor to get a presence in service fulfilment OSS markets. Table 2 summarises the estimated levels of risk.

Table 2 Porter's Five Competitive Forces Framework Applied to Service Fulfilment OSS Industry

Threat of New Entrants	**Risk**
Economics of scale	High
Product differentiation	High
Capital requirements	High
Switching costs	High
Access to distribution channels	High
Cost disadvantages independent of scale	High
Government policy	Low
Existing Competitors	
Numerous or equally balanced competitors	Medium
Slow industry growth	Medium
High fixed or storage costs	Medium
Lack of differentiation or switching costs	Medium
Capacity augmented in large increments	High
Diverse competitors	Medium
High strategic stakes	High
High exit barriers	High
Pressure from Substitute Products	
In general	Low
Bargaining Power of Buyers	
Large or concentrated buyers	High
Purchased products represent a significant fraction of buyer's costs	Low
Standard or undifferentiated products	Low
Low switching costs	Low
Low profit buyer	Medium

Buyers pose a creditable threat of backward integration	Low
Product is unimportant to the quality of the buyer's products or services	Medium
Buyer has full information	Medium
Bargaining Power of Suppliers	
In general	Low

Table 2 suggests that largest obstacles are the difficulty to enter the market and rivalry among current competitors. As discussed, these risks can be best alleviated by gaining good references from first projects and thereby strengthening partner relationships with system integrators. Due the importance of good initial references, the product scope should be set to attainable.

6 Analysis of NGN Service Fulfilment Solutions

In the past service fulfilment OSS vendors have mainly focused on mobile service activation - for example, setting up user accounts on HLR or VMS. Mobile subscriber activation does not require network provisioning. Many new data network services will also need network provisioning, which creates new requirements for service fulfilment system.

According to the market forecast presented in Chapter 3.3.6, major growth in service fulfilment is expected. Service providers' existing, but inefficient or disintegrated service activation and network provisioning systems and processes are causing restrictions on the activation rate due to manual exception handling and problems with the customer experience. Service cannot be delivered on time, with reasonable cost.

Service provider's operation environment was analysed in Chapter 3, and it led into the conclusion that in order to offer services profitably, an automated service fulfilment system is required. It was also concluded that although standards and frameworks exist, there are no clear guidelines for best-of-class solution architecture. In Chapter 4 the software modules that could be used for NGN service fulfilment solution were presented, and also the general architecture was outlined. In this chapter it will be analysed what kind of solution scenarios are feasible for service fulfilment OSS vendors and the same time attractive to the market (market analysis was implemented in Chapter 5).

6.1 Tactical and Strategic Solutions

While some service providers prefer to have a specified OSS per technology domain, others focus on centralising many domains under a common OSS platform. With domain-specific solutions we refer to *tactical* solutions which address particular technology based services, such as DSL, VPN and VoIP. These solutions provide both service activations and network provisioning, i.e. they contain both the activation engine and resource inventory. While these solutions are enjoying success through their tactical deployment into OSS, a question remains whether they are capable of handling convergent solutions in the longer term. However, the fact is that they are still successful, and especially service providers with greenfield deployments prefer modular OSS solutions, because they allow service providers to make incremental investment decision according the changing needs of network management. [Sha05]

The *strategic* solutions on the other hand can handle several technological domains, and therefore better enable the management of converged services. And as discussed in Chapter 3.3.6, there is a definite demand for solutions capable of versatile network management in several technological domains. The complexity of network provisioning is driven largely from the network complexity, but is even increased due to numerous technology-specific activation solutions, each responsible for a technology domain of the network with no communication with other domains. This complexity translates into inefficient network provisioning increasing operational expenditures, reducing the ability of the organisation to respond to market changes, and a reducing quality of the customer experience. Eventually, service providers will recognise that many of their problems arise from tactical solutions with poor (or non-existent) integration, and will want to resolve this issue through a convergent OSS that provides a convergent offering across multiple network technologies and service types. The ability to react to market changes in a timely fashion is also a major concern for operators. This is partly a result of tactical solutions and OSS architectures which do not apply modular and re-usable design concepts.

Though strategic solutions should be preferred in the long run, the present day network environment encourages tactical solutions that enforce modularity and are extendable to grow into strategic solutions. Technologies are fairly new, lots of standardisation and development work is being done, and there are service providers with not that much knowledge of daily management routines. Therefore it is better to have a best-in-class DSL or fibre access management solution and expertise, than a platform capable of managing only parts of access, metro and core networks. High level domain expertise also makes it possible to offer professional services about the best-practises, making the customer relationship more valuable.

6.2 Solution Analysis

Three different solutions are identified and evaluated:

- residential broadband with Triple Play focusing on access network service fulfilment,
- metro and core network management solution for managing e.g. MPLS networks, and

- general network management solution for more advanced network management, including e.g. service assurance functionality.

The feasibility of these three solutions is analysed in the next chapters.

6.2.1 Residential Broadband with Triple Play

The focus of NGN service fulfilment is in consumer broadband services. Network provisioning is largely associated with broadband services because there is a direct allocation of network resources to a customer.

Triple Play offering can consist of high-speed Internet connectivity, VoIP, IPTV, VoD and other value-added services. The offered services will vary widely depending on the service provider's network environment, which makes each delivery case very different. The service set should be managed using Service Management product, because thereby it is possible to reuse common pieces in separate delivery projects. The service fulfilment process for Triple Play requires:

1. account setup with the Internet Service Provider, Softswitches (for VoIP), interactive TV broadcast servers etc.,
2. setup of the IP connectivity, requiring provisioning of Provider Edge (PE) routers,
3. setup of e.g. DSL connectivity, always requiring allocation of a DSL port, but often requiring IP and Ethernet/ATM configuration, and
4. in extreme cases, exchange and access network re-wiring is also required.

While the first item requires only service activation and can be handled by the activation solution, others must be supported by the network inventory, containing the existing network and its available capacity for allocation to services. The volume of stored information affects on the simplicity of implementation. If service providers are willing to store e.g. physical network as well, the solution scope will be extensive.

It is important to notice that broadband access network provisioning requires rather complex workflow, which can be effectively defined using Activation product and Provisioning Logic Configuration Tool. A large library of network element interfaces (NEI) is also required for sending the commands to network elements. Although the given example is DSL specific, similar concepts apply to other access network scenarios. The required access network provisioning actions and their workflows were discussed in Chapter 3.3.3.

To be successful, a service fulfilment OSS vendor should expand its domain specific expertise, and also consider partnering with system integrators. When service providers decide to either enhance or completely re-establish their service fulfilment process and platform for broadband, whether DSL, cable or fibre access network, the projects are generally very large and take time and money. Therefore, in order to be considered as a creditable OSS vendor, wide expertise is required. Also, because the main responsibility is usually given to system integrator, the partnering alternative, where the main focus would be on delivering COTS software and not that much on services, is important for a NGN service fulfilment OSS vendor.

6.2.2 Metro and Core Network Management

The most apparent metro or core network service that requires network provisioning is enterprise VPN. Although the provisioning actually occurs on the edge of metro or core network, the VPN provisioning (Chapter 3.3.4) can still be included in this category, because the core network structure affects the provisioning process. However, from the service fulfilment solution point of view these services require a different type of approach than the broadband services presented in the previous chapter. Now the main focus is not only in the service activation, but in the traffic monitoring and measuring functions, which are very important as well. Actually, service activation occurs quite rarely, because it is not necessary to establish VPNs as often as activate new broadband subscribers. Network monitoring functions instead must be extensive.

In order to make the service fulfilment solution more applicable for metro and core network management, the architecture presented in Chapter 4.5 must be revised. The network monitoring interfaces should also be implemented directly between network inventory and network elements. A reconciliation module in the network inventory should be developed to be easily extendable, so that new monitoring capabilities can be added incrementally.

Implementing MPLS and Metro Ethernet specific management functions, such as establishing new LSP for traffic engineering, must be evaluated as well. LSPs for example are changed quite rarely, so is there need for automatic activation and is it necessary to record such information into network inventory? Most likely LSPs are only allocated per group of VLANs (etc.), so modelling and automating such process into service fulfilment system is not necessarily effective. Some service providers might anyhow require this, and therefore the platform must be kept very extendable, so that customer specific additions are possible. However, the objective should be to make COTS solution, which means that customer specific additions should be attached to core product.

6.2.3 General Network Management

In Chapter 3.3.6 it was highlighted that NGN service fulfilment solution should contain features that are traditionally connected to service assurance and general network management solutions. These include such functions as the ability to monitor the network, use auto-discovery to find new network elements and their configurations automatically, traffic engineering, and execute only occasional management tasks, such as setting up the routing protocols, to network elements. Another concept belonging to this category is SLA management, which was discussed in Chapter 3.4.2, and is actually closely related to VPNs. While such functionality is important in NGN service fulfilment in the long run, in the first phase NGN service fulfilment OSS should concentrate on automating the broadband service fulfilment process, because not only the software architecture, but also the existing expertise is better suited for that. Access networks should be prioritised to metro and core networks, because there the demand for automated service fulfilment is higher. However, in the long run the metro and core network management capabilities can be addressed, including the network monitoring and other features from non-traditional service fulfilment solutions.

Another interesting field of network management would be the management of large enterprise networks, discussed in [Cal04]. However, the current solution architecture is more suitable for larger deployments. Although for example VLANs are often managed manually, the initial deployment costs of the current solution architecture outweigh the benefits. Enterprises also see investment on IT infrastructure mainly as an expense, because they cannot relate it to any outcomes, such as service providers can to selling services. However, increased modularity, especially in case of network inventory, can eventually make this solution scenario more profitable, because it would allow compiling a lighter version of the service fulfilment solution.

Another noticeable network management trend is the growth of hosted IT services. According to [OSS07] the demand for managed and hosted services is increasing, because many enterprises are lacking of IT skills and are therefore willing to purchase IT services from service providers. In service fulfilment these kinds of solutions require more order and inventory management related functions and less service activation. The required functionality very closely resembles the previous solution scenario; management of large enterprise networks. However, now the solution would scale better, because the service provider could use the same solution for managing networks of several enterprises. From the service fulfilment platform this kind of usage requires a large number of added features.

6.3 Summary

Table 3 summarises the criteria that were used in evaluating the different solution scenarios. The figure has been divided into solution specific sections. The columns from left to right identify the technology, technology utilisation rate, level of required automation, difficulty of interface implementations and technology modelling, and the impact on system scope.

Table 3 Solution and Technology Analysis

	Technology Utilisation Rate	**Demand for Automation**	**Difficulty of Interface Modelling**	**Difficulty of Technology Modelling**	**Impact on NGN Service Fulfilment System Scope**
Residential Broadband					
XDSL	High	High	Low	Medium/High	Low
FTTx	Medium	High	Low	Medium/High	Medium
Cable	Medium	High	Low	Medium/High	Medium
Internet Subscription	High	High	Low	Medium	Low
VoIP	Low	High	Low	Low	Low
IPTV	Low	High	Low	Medium	Low
VoD	Low	High	Low	Medium	Low
Metro and Core Network					
Metro Ethernet (VLAN etc.)	Medium	Medium	Medium	Medium	Medium
MPLS (LSP etc.)	Medium	Low	Medium	Medium	Medium
ATM	Medium	Low	Medium	Medium	Medium
Frame Relay	Medium	Low	Medium	Medium	Medium
SDH/SONET	Medium	Low	Medium	Medium	Medium
VPN (VPLS, MPLS etc.)	Medium	Medium	Medium	High	Medium
General Network Management					
Traffic Engineering	Medium	High	High	High	High
Network Monitoring	High	High	High	High	High
Managed Services	Medium	Medium	High	High	High
SLA	Medium	High	Medium	High	High
Auto-Discovery	Medium	High	High	High	High

From Table 3 it can be concluded that technologies with high utilisation rate and demand for automation, low difficulty of interface implementations and technology modelling, and low impact on system scope should be preferred. A residential broadband solution with xDSL access, including support for Triple Play services, is best suited for service activation OSS vendors' current capability sets, and therefore offers the best alternative for competitive NGN service fulfilment OSS market entry. Strong experience with service activation encourages concentrating on commonly occurring service fulfilment actions that require a high level of automation. Technologies that are closer to core network should be supported in the long run. After that, the system applicability to general network management should be evaluated. Chapter 4.6 introduced the challenges related to network monitoring and other management functionality, and for those reasons the initial focus should be on integrating the system with other network monitoring and management applications (OSS).

7 Conclusions

7.1 Results

Technological issues, i.e. lack of generally accepted frameworks and diversity of NGN technologies and services, are challenges when implementing NGN service fulfilment OSS. However, these issues also increase the demand for management software. Based on the research, it can be concluded that NGN service fulfilment OSS sector will grow and can be an interesting opportunity for OSS vendors who have been strong in mobile service activation.

Market analysis (Chapter 5) shows that the greatest obstacles for service fulfilment OSS vendors are related to market entry and existing players. The OSS vendors can manage the risk through product differentiation and by building up a very good reputation among their first customers.

The greatest Return on Investment (ROI) is achievable when the initial solution scope focuses on delivering first-class residential broadband. This is a tactical approach (as defined in Chapter 6.1), but in the long run the scope should be extended to strategic, i.e. metro and core network and general network management functions should be added. It can be summarised that the scope of the service fulfilment solution should be extended in the following order:

1. residential broadband, including IP services,
2. metro and core network management, and
3. general network management.

The current service fulfilment solutions are best suited for automating the transaction-driven processes that are related to subscriber activation.

7.2 Assessment of Results

The results are valid, i.e. they respond to the original research question and define the preferred solution strategies. However, the validity could be significantly improved by analysing the three described solution strategies more thoroughly, especially from a technical perspective.

The general reliability of the results is arguable. As the research is solely based on literature survey and no data was collected through interviews, the study contains many assumptions, because the studied OSS industry is currently in a state of flux and therefore literature is either non-existent or disorganised. The market data that was e.g. used in concluding that service fulfilment OSS markets will grow is definite, but analysis on the feasibility of available software modules is less reliable. This is because service providers' requirements for service fulfilment OSS are not exactly known, and because the available software modules are technically evaluated only in modular level.

The results are relevant, but do not necessarily disclose much new information. The presented service fulfilment OSS solutions are quite generic, i.e. they do not describe the solution architecture and concept in a level that is detailed enough to produce an actual, sellable product. The research would have been more relevant if it had concentrated on a more specific topic, such as service fulfilment for residential broadband, and contained a case study. Thereby it would have been possible to focus more on domain specific issues and avoid generalizations.

7.3 Exploitation of Results

The implemented research can be used as a general guideline when evaluating the structure and scope of the existing service fulfilment OSS solution. It is recommended that in the current business environment and with the current expertise, OSS vendors' service fulfilment solutions concentrate on automating the transaction-driven processes and recording only service related information into network inventory. There is currently a lack of commonly accepted network management standards, which complicates the implementation of a general network management system capable of network monitoring, alarm handling, etc. However, the architecture should be kept flexible so that such functionality can be added later.

7.4 Future Research

Service providers' requirements for NGN service fulfilment OSS should be researched. Various service providers should be interviewed and their current service fulfilment process should be analysed. Based on this, it would be possible to evaluate the applicable solution architecture.

Future research activities could also include a study evaluating an actual standard-based service fulfilment system implementation. Standardisation work done by TeleManagement Forum (TMF) and other organisations should be studied more thoroughly to estimate the optimal framework for a NGN service fulfilment system.

It is also recommended to implement a case study that describes the technical implementation of the suggested service fulfilment solution in a specific customer case. It should be analysed and measured how much this solution improves the current service fulfilment process. This research would increase the domain knowledge, both from both the technical and business point of view, and provide a good tool for marketing purposes.

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